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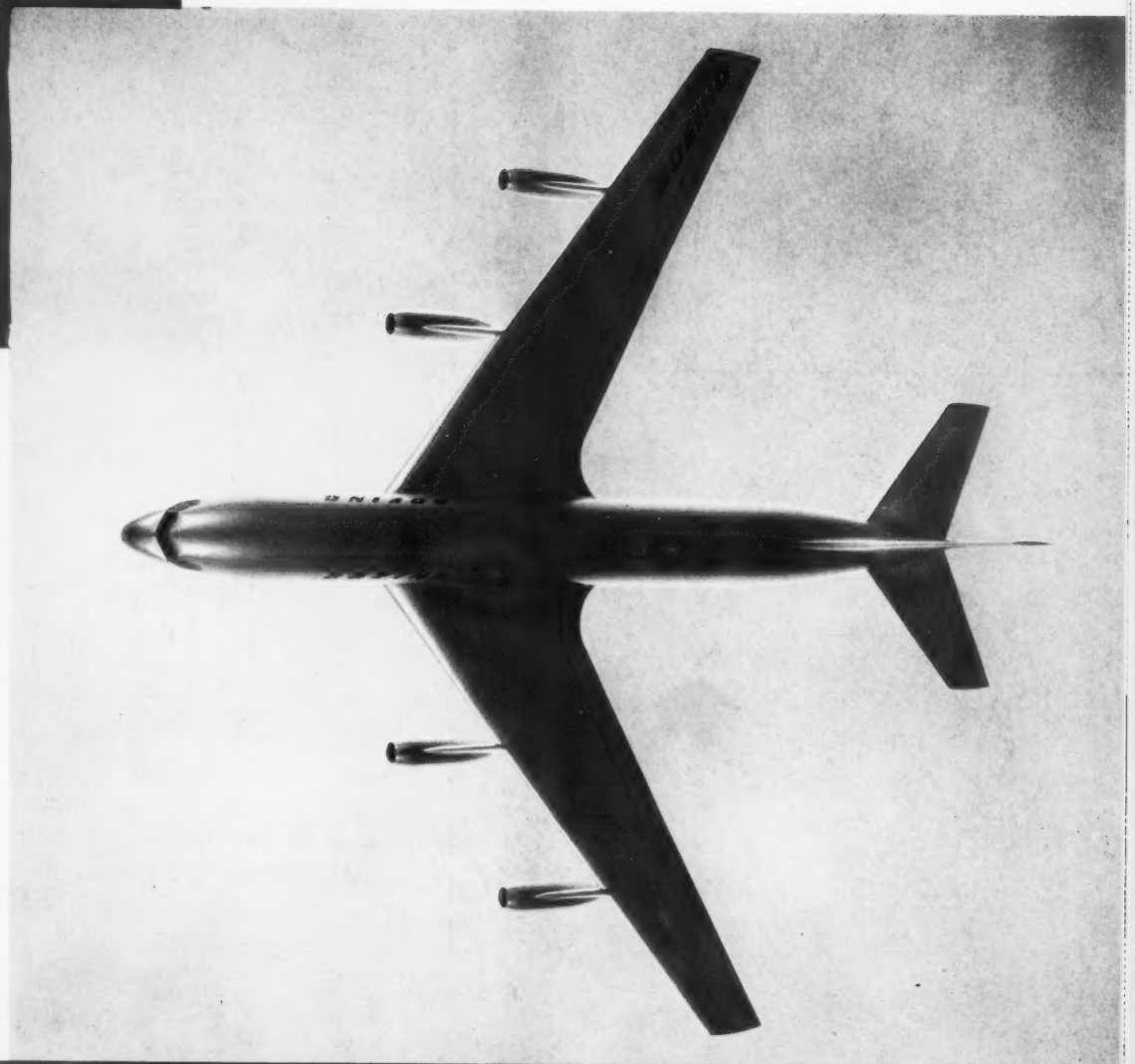

APRIL, 1954

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LEADER IN THE DESIGN, DEVELOPMENT AND MANUFACTURE OF AVIATION FUEL METERING DEVICES

Aeronautical Engineering Review

Vol. 13 — No. 4 April, 1954

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Cover—This is an exact scale model of the new four-jet 190,000-lb. transport-tanker prototype, being built by Boeing Airplane Company at its Renton, Wash., plant. America's first jet-powered transport, it represents a private investment by Boeing of more than $15,000,000. The ship is 128 ft. long, has a wing span of 130 ft., and has a cruising speed in the 550-m.p.h. class. Another photograph of this Boeing prototype may be found on page 84 of this issue.

Published Monthly by the

Institute of the Aeronautical Sciences, Inc.

2 East 64th Street, New York 21, N.Y.

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I.A.S. News Notes

April 1954

"AVIATION AND ELECTRONICS LOOK AHEAD"

This is the theme of a joint two-day meeting being held at The Franklin Institute, Philadelphia, Pa., on April 22 and 23. Sponsoring organizations are the Philadelphia Section of the IAS; Franklin Institute R. & D. Laboratories; Philadelphia Chapter of the IRE; and the Radio Technical Commission for Aeronautics. A reception and buffet supper on the 22nd, and luncheons on both days, are included in the program.

* * * * * * * *

FOURTH ANNUAL WEST COAST STUDENT CONFERENCE

Eleven colleges and universities will be represented at the IAS West Coast Student Conference in Los Angeles May 6-8. In addition to the presentation of papers, awards, and a banquet at the IAS building, the program will include field trips to Douglas and Lockheed plants, Western Airlines, UCLA, and Cal Tech.

* * * * * * * *

IAS ST. LOUIS SECTION STUDENT COMPETITION

The first annual Student Paper Competition presented by the St. Louis Section will be climaxed with the presentation of winning papers at a dinner meeting on May 26. Invitations to participate have been extended to undergraduate students at engineering colleges throughout the Midwest. Anyone desiring further information should contact C. D. Lundergan, Parks College of St. Louis University, East St. Louis, Illinois.

* * * * * * * *

NEW IAS CORPORATE MEMBERS

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NATIONAL MEETINGS CALENDAR

June 21-24 Annual Summer Meeting, IAS Building, 7660 Beverly Blvd., Los Angeles, California.

Aug. 9-11 Turbine Powered Air Transportation Meeting, Seattle, Washington.

* * * * * * * *

CALENDAR OF SECTION MEETINGS

Apr. 6--Baltimore Section: The Johns Hopkins University. Meeting, 8:30 p.m. "The Upper Atmosphere; Where the Meteorologist Stands Today" by Brig. Gen. Thomas S. Moorman, Jr., Deputy Commander, USAF Air Weather Service.

Apr. 6--San Diego Section: IAS Building. Meeting, 7:45 p.m. "Landing Gear Design" by Wilfred Nugent, Senior Design Engineer, Convair.

Apr. 7--Philadelphia Section: Engineers Club. Dinner, 7:00 p.m.; Meeting, 8:00 p.m. Speaker, Frank Piasecki, Chairman of the Board, Piasecki Helicopter Corp. Subject not known at press time.

Apr. 14--Niagara Frontier (formerly Buffalo) Section: Memorial Hall, Tonnewanta Veterans Club, Kenmore, N.Y. Meeting, 8:30 p.m. "Naval Aviation in Korea" by Vice Adm. John D. Moss, USN (Ret.), Bell Aircraft Corporation.

Apr. 15--Los Angeles Section: IAS Building. Social hour, 6:00 p.m. Dinner, 7:00 p.m.; Meeting, 8:15 p.m. "Living Through 100 g's" by Lt. Col. John Paul Stapp, USAF (MC), Holloman AFB, N. M.

Apr. 22--New York Section: Fairchild Engine Division, Fairchild Engine and Airplane Corporation, Farmingdale, L.I., N. Y. Subject, "Use of Small Turbojet Engines in Pilotless Aircraft." Hour of meeting and speaker(s) not known at press time.

Apr. 22--San Diego Section: IAS Building. Social hour, 6:30 p.m.; Dinner, 7:00 p.m. "Aircraft Flight Testing" by Capt. T. F. Connolly, USN.

Apr. 23--Hagerstown Section: Terrace Restaurant. Meeting, 8:00 p.m. Speaker, T. A. Harris, Chief, Stability Research Division, Langley Aeronautical Laboratory, NACA.

Apr. 28--St. Louis Section: Engineers Club. Meeting, 8:00 p.m. "Boundary-Layer Control Research with the Sailplane" by August Raspet, Head, Aerophysics Department, Engineering Research Station, Mississippi State College.

Apr. 29--Los Angeles Section: IAS Building. Meeting, 7:30 p.m. "Simplicity--Key to Producibility" by E. A. Green, Lockheed Aircraft Corporation.

May 1--Los Angeles Section: IAS Building, Fifth Annual Spring "Test Hop;" 9:00 p.m. to 1:00 a.m. Theme, "May Day--Pre-Marxian Concept." Music by Ben Brown and his Orchestra.

May13--Los Angeles Section: IAS Building. Meeting, 7:30 p.m. "Applications of Operations--Research Techniques of Airborne Weapons Systems Planning" by Robert A. Bailey, Lockheed Aircraft Corp.

May 26--St. Louis Section: Spring Dinner Meeting and First Annual Student Paper Competition. Location and time not known at press time.

June 16--Washington Section: Inspection trip to Naval Air Test Center, Patuxent River, Maryland.

* * * * * * * *

IAS News

A Record of People and Events of Interest to Institute Members

Notes on IAS Luncheon Speeches

von Kármán, de Florez, Lee, and Powers Present Luncheon Talks at Recent IAS Annual Meeting

DURING THE Twenty-Second Annual Meeting of the Institute of the Aeronautical Sciences (January 25–29 at the Hotel Astor, New York), four well-attended luncheons were held. The Guests of Honor and Principal Speakers at these luncheons were: Dr. Theodore von Kármán, Chairman, Advisory Group for Aeronautical Research and Development, North Atlantic Treaty Organization; Rear Adm. Luis de Florez, USNR, Chairman of the Board, The de Florez Company, Inc.; The Honorable Frederick B. Lee, Administrator, CAA; and Major Gen. Edward M. Powers, USAF (Ret.), Vice-President and General Manager of Curtiss-Wright Corporation's Wright Aeronautical Division.

Dr. von Kármán spoke at the first of these luncheons, which was held on January 26. An IAS Honorary Fellow and Founder Member, Dr. von Kármán discussed the organizational setup of AGARD, its purposes, its accomplishments of the past, and its plans for the future.

At the second luncheon on January 27, Admiral de Florez, an IAS Fellow and Founder Member, discussed the major role played by electronic devices in saving lives, time, and money in promoting aviation. He stated that, because of such considerations as expense in developing various electronic devices, the pilot would remain an essential figure in aviation. It was the speaker's suggestion that the extensive use of flight simulators in training pilots in emergency procedures would definitely increase flight safety and could gain for the pilot those "few precious seconds that could mean the difference between life and death." Admiral de Florez declared that the use of electronic devices was so widespread that the air lines would be unable to conduct operations without them.

The third luncheon speaker was Mr. Lee, an IAS Honorary Member and Member, who opened his lecture on the "Changing Role of the Federal Government in Aviation" by defining the CAA's basic mission as fostering "the safe and rapid movement of aircraft on interstate routes." In the first part of his talk, he outlined the means now being used to increase safety and save both time and expense. This method involves delegating responsibility to CAA agents in the field and to industry for the proper certification of aircraft and aircraft components. In this regard, Mr. Lee stated that "the practice of designating industry personnel as CAA examiners has been extended to virtually every phase of safety activity." CAA agents, he stated, are expected "to be helpful counselors in the common cause of safety, with the ability to analyze and evaluate problems as they arise in the shop and in the air." In the second and concluding portion of his address, Mr. Lee touched upon the CAA's operation of the Federal airways and the changes now being effected to meet more economically and efficiently the demands of a growing air traffic.

The luncheon speakers at the recent IAS annual meeting are *from left to right:* Dr. Theodore von Kármán; Rear Adm. Luis de Florez, USNR; The Honorable Frederick B. Lee; and Major Gen. Edward M. Powers, USAF (Ret.).

General Powers, AFIAS, the speaker at the final luncheon on January 29, gave a brief commentary on the history of flight and its future. He began by comparing aircraft of World War I and the 1920's with those of the present day. He then went on to predict that "in some 10 or 15 years you gentlemen will come to regard the jet transport as a commonplace high-speed vehicle of transportation operating between large centers of population and long hauls." The speaker felt that "aircraft will carry more and more of the freight and express shipments of the world, for commercial and military purposes" and that "the turbopropeller type of power plant has high promise for heavy load carrying in these fields, also for passengers on certain routes." He emphasized the continuing need for aeronautical scientists and engineers to dedicate themselves "to research and development" and stated that those "responsible for design and development must devote a larger proportion of their time and talent to the producibility of models they deliver to the shop for production," thus saving "time and money."

IAS Members Head National Aeronautical Honorary Society

Sigma Gamma Tau, a national aeronautical honorary society founded on February 28, 1953, at Purdue University by the merging of Tau Omega and Gamma Alpha Rho, has elected four members of the Institute of the Aeronautical Sciences to its executive staff. These are: National President, L. A. Comp, MIAS, Professor of Aeronautical Engineering, University of Oklahoma; National First Vice-President, Henry Burlage, Jr., MIAS, Assistant Professor of Aeronautical Engineering, Case Institute of Technology; National Second Vice-President, Melvin H. Snyder, Jr., MIAS, Associate Professor and Head of Aeronautical Engineering Department, University of Wichita; and National Secretary-Treasurer, Harry H. Hilton, MIAS, Assistant Professor—Aeronautical Engineering, Department of Aeronautical Engineering, University of Illinois.

This society now has 14 chapters in the United States. Membership in it is limited to students in Aeronautical Engineering or in Aeronautical Engineering options in accredited universities or colleges who are Juniors, Seniors, or Graduate students of high scholastic ability and character.

It is the desire of Sigma Gamma Tau to extend its scope of activities and open chapters at other accredited universities or colleges. Accordingly, any accredited university or college that wishes to obtain information relative to opening a Sigma Gamma Tau chapter should contact Professor Hilton, the society's National Secretary-Treasurer.

Reaction Motors Joins IAS

Reaction Motors, Inc., of Rockaway, N.J., has become a Corporate Member of the Institute of the Aeronautical Sciences. This corporation was the first in the United States to be established solely for the purpose of research, development, and production of rocket-type power sources and their accessory equipment. At the present time, liquid-propellant rocket engines are the primary product of the company's operations. While the principal applications for such power sources are supersonic aircraft and guided missiles, other uses for rocket engines and related principles of high-energy combustion are also under development.

Complete rocket engines are developed, fabricated, assembled, and tested by the company. The design, development, and fabrication of accessory control equipment, such as pressure regulators and sensors and pneumatic valves and switches, constitute another important product group.

Reaction Motors also conducts research investigations relating to improved rocket-type propellants and propellant systems, rocket-engine design parameters, the scope of rocket power applications, etc. Design studies are conducted to investigate new and advanced techniques for improving rocket-engine design characteristics and for overcoming unusual problems, such as are presented by the high temperature of propellant combustion, the high speeds involved in exhaust velocities and gas-turbine pumps, and the high pressure in cylinder operation.

A considerable portion of the company's activity includes testing of rocket engines, components, and accessories, both on fixed test stands using the actual propellants and in the laboratory for hydrostatic and bench testing.

In addition to the fabrication and assembly of rocket-engine components and accessories, Reaction Motors manufactures spare parts and special tools for field maintenance of rocket engines and overhauls engines used in field operations.

Other company activities include engineering consultation and testing services, training programs for rocket specialists, and field service representation.

Dr. C. C. Furnas, FIAS, Director, Cornell Aeronautical Laboratory, Inc., has been appointed Chairman of the recently formed Technical Advisory Panel on Aeronautics of the Department of Defense. The panel is composed of civilian scientists and experts. Its purpose is to develop technical advice as required in the fields of air frames, propulsion systems, aerodynamics, and equipment and components for both piloted aircraft and guided missiles. The panel is working closely with the various military committees responsible for the actual execution of research and development programs.

Eight Aeronautical Companies "Excellently Managed"

According to a recent report, eight companies in the aviation industry have been certified by the American Institute of Management for its designation of "excellently managed" for the year 1953. These companies are: American Airlines, Inc.; Douglas Aircraft Company, Inc.; Grumman Aircraft Engineering Corporation; Lockheed Aircraft Corporation; North American Aviation, Inc.; Sperry Gyroscope Company, Division of The Sperry Corporation; Thompson Products, Inc.; and United Aircraft Corporation.

Penn State to Present Short Courses

The Pennsylvania State University will present two 5-day courses designed to give a broad coverage of high-temperature properties of materials and the mechanics of creep by including physical, metallurgical, and design aspects of these subjects. The first course, which will be on "High Temperature Properties of Materials," will be held at Penn State between June 21 and 25. The second course, "Mechanics of Creep," will be conducted at the university from June 28 to July 2, inclusive. Authorities from industrial, Governmental, and educational institutions will deliver the lectures for both courses.

For further information, please write to Dr. Joseph Marin, Department of Engineering Mechanics, The Pennsylvania State University, State College, Pa.

Necrology

Noel W. Bouley

Noel Warner (Jeff) Bouley, MIAS, Assistant Chief Engineer, San Diego Division, Consolidated Vultee Aircraft Corporation, died on January 24 in Scripps Memorial Hospital, San Diego, after a brief illness.

Born in Aberdeen, S.D., on March 10, 1907, Mr. Bouley received his B.S. degree in Aeronautical Engineering (cum laude) in 1933 from the University of Washington.

After graduating from Washington, he became a member of the Engineering Department of Boeing Airplane Company. He left Boeing in 1936 to begin an association with Convair which lasted until his death. He began with Convair as a Layout Draftsman. In 1943, he was appointed Project Engineer of the corporation's New Orleans Division; he was made its Chief Division Engineer the following year. In 1945, he was transferred back to the company's San Diego Division as Design Group Engineer. Between 1946 and 1948, he was Project Engineer, and in 1948, he became Chief Project Engineer. He was appointed Assistant Chief Engineer in 1951.

Mr. Bouley is survived by his widow, Mrs. Claudia Higgins Bouley, and by two sons, Leon Nelson and Richard Frederick Bouley.

Volney C. Finch

Volney Cecil Finch, MIAS, Professor of Mechanical Engineering, Stanford University, died on last November 9. He was 61 years of age.

A native of Smith River, Calif., Professor Finch received his S.M. degree in Aeronautical Engineering in 1927 from Massachusetts Institute of Technology. He entered the U.S. Navy in 1917 and was trained first as a Naval Aviator and later as an Engineering Officer. He remained on active duty with the Navy until 1929, when he resigned to become Chief Engineer with Aerco Safety Rating Company.

He first became associated with the academic world in 1930 as Head of the Aeronautical Engineering Department —with the rank of Professor—at Alabama Polytechnic Institute. In 1933, he joined the faculty of Stanford University as Professor of Mechanical Engineering. Except for the period from 1941 to 1946 when he returned to active Naval duty, he remained at Stanford until his death.

Richard L. Morgan

The death of 2nd Lt. Richard Lester Morgan, USAF, TMIAS, on January 7 has been reported.

Lieutenant Morgan was born on July 3, 1931, at Mattoon, Ill. He attended high school at Mattoon, completing his work there in June, 1949. He then matriculated at St. Louis University and was graduated in June, 1952, from Parks Air College with a B.S. degree in Aeronautics. He entered the Air Force shortly after his graduation and was trained as an Air Force pilot.

News of Members

▸ **A. Francis Arcier** (AF) recently received the Meritorious Civilian Service Award, the USAF's second highest civilian honor, for his outstanding performance of duty as Scientific Advisor at the Air Technical Intelligence Center, Directorate of Intelligence, USAF, Wright-Patterson AFB, Ohio. Mr. Arcier has held this post for the last 4 years. His vast scientific knowledge and understanding was credited with greatly advancing the Air Force's intelligence program.

▸ **Dr. Daniel P. Barnard** (AF), Research Coordinator, Standard Oil Company (Indiana), was sworn in on February 1 as Deputy Assistant Secretary of Defense (Research and Development). Dr. Barnard is an IAS Founder Member.

▸ **Harlan D. Fowler** (AF) is now an Aeronautical Consultant specializing in the field of boundary-layer control for high lift, low drag, and stability. The emphasis, Mr. Fowler states, is on the practical aspect of power sources, economy of operation, and design problems associated with this important phase of development. He is now located at the Alban Towers, Washington 16, D.C.

▸ **Roswell W. Gilbert** (M) was recently appointed Assistant to the President, Weston Electrical Instrument Corporation. In addition to this new post, Mr. Gilbert is continuing to serve as Director of Research at Weston.

▸ **Najeeb E. Halaby, Jr.,** MIAS, Deputy to the Assistant Secretary of Defense for International Security Affairs, was awarded the Department of Defense Certificate of Appreciation. The presentation was made by Secretary of Defense Charles E. Wilson, HMIAS, during a ceremony held at the Pentagon last January.

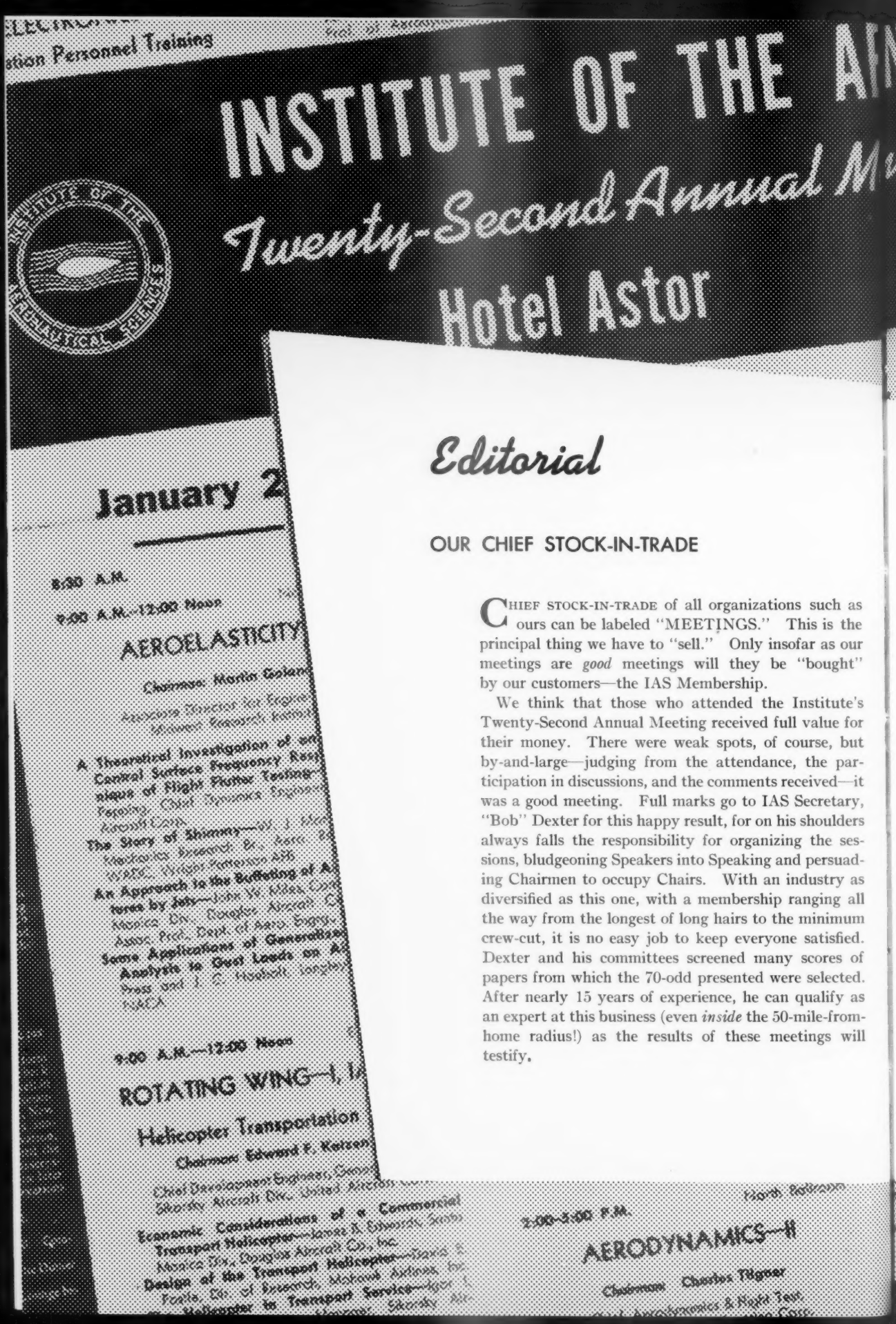
▸ **Hall L. Hibbard** (F), Vice-President —Engineering and a Director, Lockheed Aircraft Corporation, was recently elected to directorships in Lockheed Aircraft Service and its subsidiaries, Lockheed Aircraft Service-International and Lockheed Aircraft Service-Overseas.

▸ **Colonel Paul H. Kemmer,** USAF (Ret.) (F), has been appointed to the newly created post of Chief Designer in Ryan Aeronautical Company's Engineering Division. Since retiring from the Air Force in 1949, Colonel Kemmer has been an Aeronautical Consultant with private firms.

▸ **James H. Kindelberger** (HF), Chairman of the Board, North American Aviation, Inc., recently received Italy's highest civilian award, the order "Al Merito Della Repubblica Italiana." This presentation was made to Mr. Kindelberger "for his

(*Continued on page 80*)

Gilbert DeVore, MIAS, who until recently was a CAA Flight Test Engineer, has established the DeVore Engineering Service at 200 West 57th St., New York 19. Mr. DeVore, now a Consultant to the helicopter industry and specializing in civil aviation, is a CAA Designated Engineering Representative (DER).

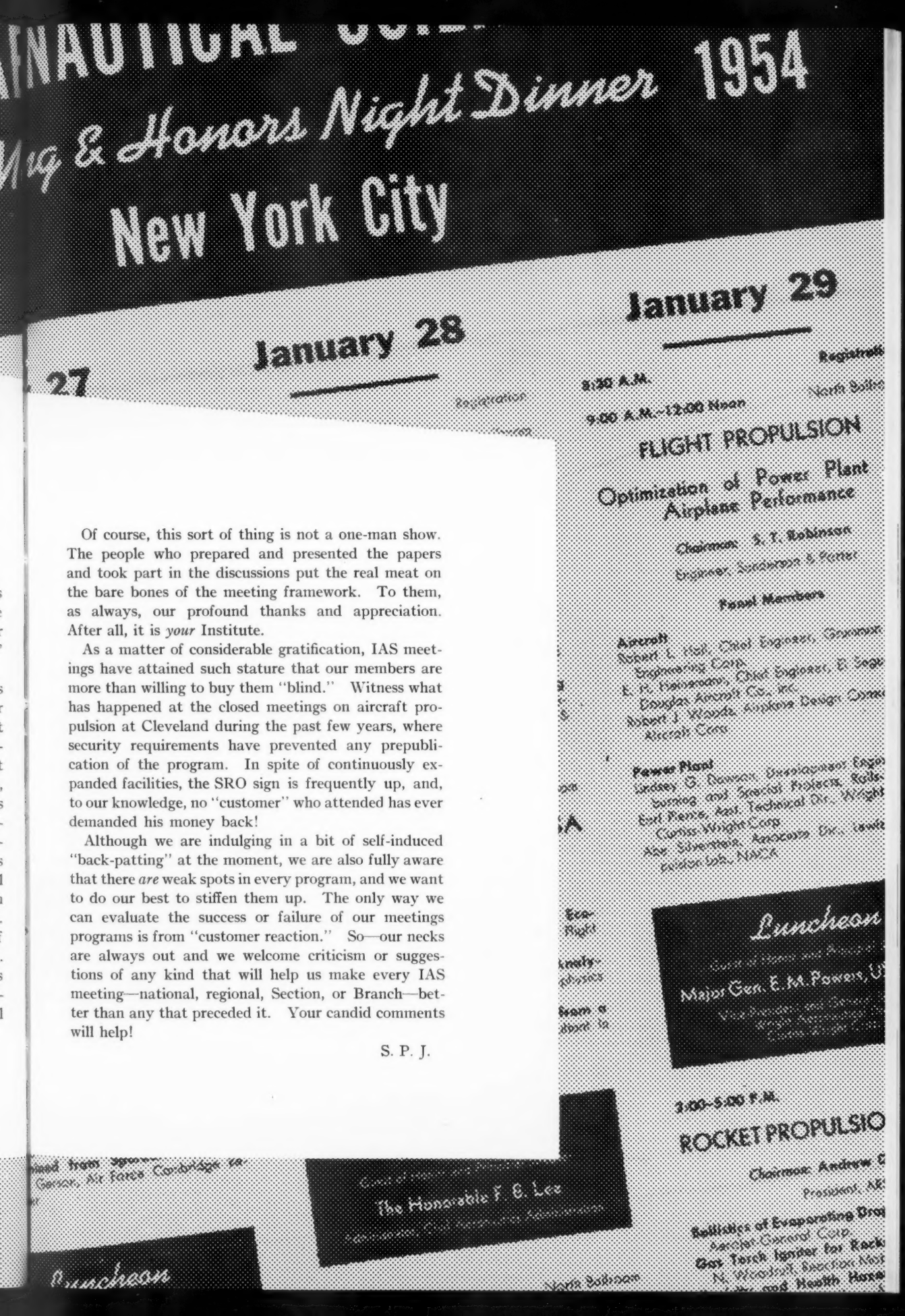


Editorial

OUR CHIEF STOCK-IN-TRADE

CHIEF STOCK-IN-TRADE of all organizations such as ours can be labeled "MEETINGS." This is the principal thing we have to "sell." Only insofar as our meetings are *good* meetings will they be "bought" by our customers—the IAS Membership.

We think that those who attended the Institute's Twenty-Second Annual Meeting received full value for their money. There were weak spots, of course, but by-and-large—judging from the attendance, the participation in discussions, and the comments received—it was a good meeting. Full marks go to IAS Secretary, "Bob" Dexter for this happy result, for on his shoulders always falls the responsibility for organizing the sessions, bludgeoning Speakers into Speaking and persuading Chairmen to occupy Chairs. With an industry as diversified as this one, with a membership ranging all the way from the longest of long hairs to the minimum crew-cut, it is no easy job to keep everyone satisfied. Dexter and his committees screened many scores of papers from which the 70-odd presented were selected. After nearly 15 years of experience, he can qualify as an expert at this business (even *inside* the 50-mile-from-home radius!) as the results of these meetings will testify.



Of course, this sort of thing is not a one-man show. The people who prepared and presented the papers and took part in the discussions put the real meat on the bare bones of the meeting framework. To them, as always, our profound thanks and appreciation. After all, it is *your* Institute.

As a matter of considerable gratification, IAS meetings have attained such stature that our members are more than willing to buy them "blind." Witness what has happened at the closed meetings on aircraft propulsion at Cleveland during the past few years, where security requirements have prevented any prepublication of the program. In spite of continuously expanded facilities, the SRO sign is frequently up, and, to our knowledge, no "customer" who attended has ever demanded his money back!

Although we are indulging in a bit of self-induced "back-patting" at the moment, we are also fully aware that there *are* weak spots in every program, and we want to do our best to stiffen them up. The only way we can evaluate the success or failure of our meetings programs is from "customer reaction." So—our necks are always out and we welcome criticism or suggestions of any kind that will help us make every IAS meeting—national, regional, Section, or Branch—better than any that preceded it. Your candid comments will help!

S. P. J.

22nd Annual Meeting

New York

Jan. 25–29, 1954

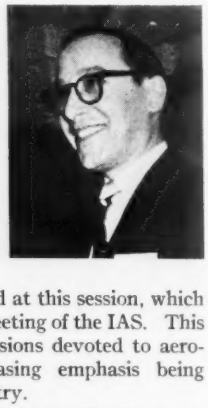
Summary of Technical Sessions

The Institute and the REVIEW are indebted to the individual chairmen of the various technical sessions at this year's Annual Meeting—both for the excellent manner in which they conducted their sessions and for their cooperation in providing the following reports.

Because of space limitations in the magazine and the unusual number of papers and sessions presented at this year's meeting, it has been necessary to divide the publication of these summaries between this and later issues of the REVIEW.

Many of the papers will be published in full in subsequent issues of the REVIEW and JOURNAL. Preprints of some of the papers are available. A list of these may be found on page 130 of the March issue of the REVIEW—Ed.

Aeroelasticity—I



By
Martin Goland

Associate Director for Engineering Sciences, Midwest Research Institute

Four excellent papers were presented at this session, which opened the Twenty-Second Annual Meeting of the IAS. This year's program contained two full sessions devoted to aeroelasticity, thus reflecting the increasing emphasis being placed on this subject within the industry.

The first paper was by Raymond A. Pepping, Chief Dynamics Engineer, McDonnell Aircraft Corporation, entitled "A Theoretical Investigation of the Oscillating Control Surface Frequency Response Technique of Flight Flutter Testing." Recognizing the importance of flight flutter testing and at the same time being aware of its difficulties and dangers to pilot and equipment, Mr. Pepping approached the problem of conducting such tests from a refreshing and fruitful point of view. By introducing artificial stability, whose characteristics are known, into the aircraft flutter system, flight testing under otherwise dangerous conditions is made possible. By using servomechanism techniques for data analysis, the effects of the artificially introduced stabilization elements on the stability of the system can be isolated from the test data, and an accurate estimate can then be made of the safety of the prototype aircraft design. In his paper, Mr. Pepping outlined in detail the mathematical foundations for his method and provided an example of their application.

"The Story of Shimmy" by W. J. Moreland, Chief, Mechanics Research Branch, Aeronautical Research Laboratory, WADC, Wright-Patterson Air Force Base, was most effectively presented on behalf of the author by Norris W. Carlson, who was in charge of the experimental work for the program. In addition to showing a spectacular film on shimmy, Mr. Carlson outlined a theory of landing-gear shimmy which accounts for the parts played by the tire, the air frame, and the gear proper. An elaborate series of analog computations were used to clarify the mechanism of shimmy, and the utility of the analysis was demonstrated in terms of certain design rules recommended for the avoidance of the phenomena. The program is indeed an impressive example of the combined utilization of dynamical theory, modern computer application, and excellent model testing.

The last two papers were related to each other, in that both attempt the use of advanced probability theory for the solution of dynamic loading problems in aircraft engineering. Professor John W. Miles, Consultant, Santa Monica Division, Douglas Aircraft Company, Inc., and Associate Professor, Department of Aeronautical Engineering, U.C.L.A., undertook the ambitious task of evaluating the fatigue life of aircraft structural components that are stressed by buffeting from jets. In his paper "An Approach to the Buffeting of Aircraft Structures by Jets," he makes use of Lighthill's theory for jet noise, the dynamic response mechanism of a single degree-of-freedom representation of the structure dynamics, probability theory, and the concept of cumulative fatigue damage. From these, Professor Miles deduced a number of design rules for the avoidance of fatigue flutter from jet buffeting. As the author points out, much remains to be done before quantitative design results are obtained, but in a most clear and lucid presentation, Professor Miles convinced all those in attendance of the power and utility of the newer probabilistic methods.

The final paper was by H. Press and J. C. Houbolt, Langley Aeronautical Laboratory, NACA, entitled "Some Applications of Generalized Harmonic Analysis to Gust Loads on Airplanes." Through the use of generalized harmonic analysis techniques, the NACA has been making unusually effective strides toward solution of the important problem of design for gust loads, and the paper by Messrs. Press and Houbolt reviews some significant applications made to date. After summarizing several important theorems relating to generalized harmonic analysis, the spectrum of the atmospheric vertical velocity was described and was later used in a study of three significant factors involved in airplane responses to gusts—namely, the center-of-gravity, short-period damping, and wing bending flexibility. In each case, convincing experimental verification of the theoretical analysis is given. It seems inevitable that techniques similar to those described in this paper will assume an increasingly important role in future design procedures in aeronautical engineering.

Speaking on behalf of those attending the session, it is safe to say that all were intrigued and educated by the fresh ideas contained in the four presentations. In providing insight into future design techniques, the authors should be heartily commended.

Rotating Wing—I

By
Edward F. Katzenberger

Chief Development Engineer—General Design, Sikorsky Aircraft Division, U.A.C.

The helicopter appears unquestionably to be on the threshold of a very wide expansion of its use by commercial operators. While existing machines have been designed to military specifications, some have characteristics indicative of considerable promise for commercial operation. The growing evidences of the maturity of the helicopter as a commercial transport naturally have aroused the interest of operators and the aircraft industry in general. Accordingly, an effort was made to obtain authoritative and definitive papers for this Session which would: (a) set forth the design requirements for the commercial transport helicopter; (b) assess the capabilities of the helicopter industry in meeting these requirements; and (c) present a cogent summary of the major economic factors involved in making the transport helicopter a paying proposition.

In his paper, "Economic Considerations of the Transport Helicopter," James B. Edwards dealt with the economic aspects of the problem. His paper is printed in full in this issue on page 76.

The first aspect of the helicopter transport design problem, that of determining the characteristics of the machines required by the operator, was lucidly set forth both in David E. Postle's paper, "Design of the Transport Helicopter" (see page 70, March REVIEW, for full paper), and in the presentation of Byron A. Moe, "The Local Service Air Carrier Design Requirements for the Transport Helicopter." It is possibly significant that considerable agreement was noted between these two statements of required characteristics arrived at through independent study. Mr. Postle is Director of Research, Mohawk Airlines, Inc., and Mr. Moe is Director, Operational Planning, Allegheny Airlines, Inc.

Both papers were exhaustive in treatment and Mr. Postle's in particular contained a wealth of detail which should be of considerable value to the designer. Of particular importance was the clear exposition of the meaning of the term "short-haul market." At present, the bulk of such air traffic lies within the 100–200-mile bracket. The significance of a shift to shorter stage lengths will be to place a premium on the ingenuity of the designer in producing a helicopter requiring an absolute minimum of loading, unloading, and ground-service time.

It is impossible in the space available here to summarize adequately the mass of detail given in these two papers. A sampling of the more significant items can, however, be given. As has been noted, they indicate considerable agreement. For instance, Mr. Postle indicated a range requirement of approximately 200 miles. The figures given by Mr. Moe were 200–250 miles. Seating capacities were, respectively, 30 and 32 passengers, and speeds 140 and 140–150 m.p.h. The critical importance of noise was noted and rightly emphasized. For the designer this continues to be one of the most difficult problems with regard to which research has as yet failed to produce any significant results.

Mr. Sikorsky's paper, "The Helicopter in Transport Service," assumed, for purposes of developing his ideas as to the present capabilities of the helicopter manufacturers, that two types of operation would be required: the metropolitan, or intracity, and the intercity. He dealt with the first as requiring a helicopter capable of 140 m.p.h. in cruise and carrying 14 to 20 passengers, and the latter as calling for cruise speeds over 200 m.p.h. with 40 to 50 passengers. His remarks were for the most part directed to the difficult problems of rotor design, stability, and power plant posed by this severe set of requirements. He did not overlook, however, the potential of existing twin-engined helicopters in providing a long-term interim of profitable intercity service at more modest speeds. The central portion of his paper contained a lucid summary of the major problems and the status of existing knowledge and continuous research relative to forseeable solutions to these problems.

At the outset of his presentation, Mr. Sikorsky departed materially from his prepared text and gave a historical summary of some of his past achievements. This portion of his talk was illustrated by means of slides and concluded appropriately with a number of in-flight pictures of his latest achievement, the S-56 Marine Assault helicopter, a machine that may well become the first twin-engined intercity helicopter.

Aeroelasticity—II

By
I. E. Garrick

Chief, Dynamic Loads Division Langley Aeronautical Laboratory, NACA

The second session on aeroelasticity like the first was very well attended, an indication of how more and more people in aeronautics are becoming immersed in the problems of this specialized and ofttimes weird field—a field created and fed by the insistent and insatiable demands for static and dynamic *compatibility* in the union of aerodynamics and structures.

Of the four papers presented in this session, two dealt dominantly with the aerodynamics of oscillating wings of low aspect-ratio, the third was dominantly on new methods for stiffness and deflection analysis of complex structures, and the fourth dealt with an analysis of an idealized type of panel flutter. The titles and authors of the papers are listed below together with some remarks pertaining to their scope and to the discussion ensuing their presentation.

"Theoretical Aerodynamic Properties of Low Aspect Ratio Harmonically Oscillating Rigid Airfoils in a Compressible Medium: Comparison with Other Theories and Several Applications to the Prediction of Flutter," by Bernard Mazelsky, Dynamics Engineer, Lockheed Aircraft Corporation. In this paper a rather full analysis was given of the zero aspect ratio limiting case, including effects of compressibility as indicated in the title. This work was shown to coincide in part with recent independent work in Sweden of Merbt and Landahl, but because Mr. Mazelsky had available to him the excellent Bureau of Standards tables of Mathieu functions, he has gone farther in the achieved numerical results. He gave lift and moment results, both magnitude and phase, for translation, pitching, and rolling, and made application to rectangular and delta wings of low aspect ratio. He also gave comparisons normalized to steady flow conditions with recent work based on Lawrence and Gerber and on Theodorsen, and applied his results in some trend studies on flutter of simple wings. The paper was concluded with the presentation of an intriguing movie in color of some flutter tests made with the aid of rockets and photographed by a camera mounted on the rocket.

In the discussion of the paper Prof. Holt Ashley referred to some low-speed data at M.I.T. for small aspect ratio wings

and to the desirability of more sensitive indicators of the aerodynamic content than flutter itself—for example, pressure distributions. He also cautioned against the use of simple criteria in the "devilishly" difficult field of flutter. Other discussers dealt with the desirability of extending the work to include modes of deformation, of making comparison with certain exact results for deltas, and of the possible use of recently improved steady flow aerodynamics for low aspect ratio wings as a guide for further developments.

"Generalized Aerodynamic Forces on the Delta Wing with Supersonic Leading Edges," by J. Walsh, Head, Structural Dynamics Unit, BuAer, Department of the Navy; G. Zartarian, Senior Engineer, Aero-Elastic and Structures Research, M.I.T.; and H. M. Voss, Instructor, Dept. of Aeronautical Engineering, M.I.T. The presentation of the paper was in two parts, one by Mr. Walsh, the other by Mr. Voss. The object of the paper was to show how strip analysis based on two dimensional flow formulas can be made to correctly yield integrated results for generalized forces and moments for three-dimensional flow conditions of concern in flutter work wherein chosen modes of deformation are employed. The first part of the paper presented a proof of the desired property for the case of certain rigid airfoil motions. The second part of the paper presented another proof based on the reverse flow reciprocity theorems, which have been interesting enough recently themselves to be the subject of IAS papers and which are here shown to have more than abstract interest. The extent to which the procedure may be applied to flexible modes of deformation was also examined numerically and some tables of comparisons illustrating the order of approximation for various selected modes were presented.

"Stiffness and Deflection Analysis of Complex Structures," by M. J. Turner, H. C. Martin, R. W. Clough, and L. J. Topp, Boeing Airplane Company. Mr. Turner presented the paper, which dealt with a currently important structural phase of the aeroelastic problem—namely, a procedure for calculating load deflection data for complex multiweb and multirib aircraft structures. The extent to which this problem is resolved may dictate the extent to which the associated aerodynamic phase will be delved into. After a review of the recent contributions of many authors such as Schuerch, Levy, Bisplinghoff and Lang, and Reissner and Stein, a procedure was suggested of extending to shell-type structures the fundamental method of joint displacement. The structure is decomposed into spar, rib, cover skin, and stiffener segments. Stiffness coefficients are determined for each of these component units and superposition leads to the stiffness matrix for the complete structure. An important feature in the analysis is the assessment of the flexibility of a quadrilateral plate element on the basis of an energy calculation to find load-deflection relations at its corners. In the opinion of Samuel Levy, of the Bureau of Standards: "The method appears to be capable of considerably greater accuracy than any other so far available provided adequate facilities are available for inverting matrices." At the end of the paper the authors called attention to the possibility of avoiding the matrix inversion by reducing the order of the system with a system of generalized coordinates.

In the discussion, Dr. J. E. Duberg, of NACA's Structures Research Division, pointed out that it would be desirable to look into means for evaluating the approximations implicit in the analysis, and, in particular, the approximations involved in the use of corner forces might be improved by other procedures. It was stated that the authors have various numerical examples still underway at present which they had hoped to have included.

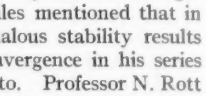
"Analysis of Flutter in Compressible Flow of a Panel on Many Supports," by John M. Hedgepeth, Bernard Budiansky, and Robert W. Leonard, Langley Aeronautical Laboratory, NACA. This paper drew attention to a problem not before presented at Institute meetings—the flutter of metal skin coverings. Some of the people who have worked on phases of the problem are P. F. Jordan (in Germany), John W. Miles, and S. F. Shen. The authors chose an idealized case of two-dimensional flow past an infinitely long panel on equally spaced supports, a problem amenable to exact treatment both for its linearized aerodynamics and for its structural content. The problem thus provided a good example and a framework for testing some of the delicate questions associated with determination of ranges and degrees of instability, and the authors presented a discussion on these matters. Some of the results which must appear strange from a physical point of view—like the familiar Glauert-Prandtl type infinity at $M = 1$—may be explained away in a like fashion or on the basis of small rate of growth of the instability and, as a whole, give clues as to the direction in which further work should proceed.

Professor Ashley thought the work the first he had seen using results of steady aerodynamics to obtain the unsteady flow results! He also thought the work, especially the study of the rate of growth of the instability, might clear up some of the puzzling results that had been found by earlier investigators at M.I.T. Professor John W. Miles mentioned that in another problem he had found anomalous stability results associated with a lack of uniform convergence in his series and that this might be worth looking into. Professor N. Rott mentioned the possible significance of effects of structural damping.

All in all—a session of significant and worth-while contributions, spirited and pointed discussion, and a generous and responsive audience.

Rotating Wing—II

By
Lt. Colonel R. Williams, USA
Office, Chief of Staff
Department of the Army



In the first paper, "Problems of Slow Speed Flight in Helicopters," Comdr. H. S. Brown, Jr., Head of Rotary Wing Design, Aircraft Division, Bureau of Aeronautics, outlined the problems associated with slow speed flight of helicopters at low altitudes and the present approaches to the solution of these problems. Electronic devices, utilizing gyro sensing elements, will be relied upon to provide stability in the helicopter. The device will indicate not only the magnitude of the displacement from the desired attitude of the helicopter but will also give the pilot an indication, through the control system, of the proper direction of control movement required to correct the attitude of the helicopter. Present helicopters are capable of blind flight, including instrument landings and GCA approaches. At the present time, however, it is not possible to hover on instruments over a fixed position on the surface of the earth or ocean. It is hoped that within 2 years a completely blind flying helicopter will be available. During the questions that followed the paper, Commander Brown indicated that the altitude controller did not have to follow the swells but could average the vertical height of the waves.

In the second paper, "Concepts of Component Testing," Bartram Kelley, Chief Engineer, Helicopter Division, Bell Aircraft Corporation, discussed the overall aspects of com-

ponent testing as applied to the six major elements of the helicopter. These elements are: the landing gear, the fuselage, the transmission, the shafting, the flight controls, and the rotors. In the early days of helicopter design, the machine was first flown and then consideration given to measuring the loads actually occurring in flight. This concept has now been improved to permit calculations of flight loads and extensive testing of the components prior to flight of the helicopter. Mr. Kelley concluded that the landing-gear test criteria should depart still further from that applied to the airplane and should have additional emphasis on ground handling in rough terrain and on crash conditions. The design of the fuselage is governed largely by stiffness. Methods for predicting the loads and for fatigue testing the units are fair or good for all other components except the rotor. The rotor whirl testing is useful for endurance and maintenance purposes but cannot replace the fatigue testing. Fatigue testing can be accelerated by testing components separately in order to apply the desired load to each component.

In the third paper, "Development Problems of the Large Helicopter," L. L. Douglas, Vice-President—Engineering, Piasecki Helicopter Corporation, reviewed the basic parameters effecting the design of large helicopters. His paper is published in full on page 60 of this issue.

In the last paper, "Development of New Cargo Helicopters," D. M. Thompson, Office of Chief of Transportation, Department of the Army, discussed the relative importance of cruising speed, pay load, availability, and ground loading time upon the ability of the cargo helicopter to perform the cargo mission. It was concluded that the greatest single factor governing the amount of cargo which any helicopter can transport per day is the availability of the machine. The next most important parameter is rapid loading and servicing on the ground. Cruising speed and pay load have relatively little importance on the amount of cargo delivered per day. The second part of the paper was devoted to an analysis of the high cost of maintenance of present-day cargo helicopters. The cost of operation of a six-passenger helicopter is as equal to that of a 21-passenger air liner. The cost of spare parts alone for a small helicopter is in excess of $80 per hour. This high cost of spare parts indicates to the customer that, since these parts are purchased for installation on the helicopter, availability of the machine will be poor because of the large amount of time spent on the ground having parts installed. This high cost of spare parts places the customer in the unfortunate position of being forced either to reduce future production in order to buy spare parts with the limited funds available or to continue to build helicopters that will be grounded by lack of spare parts. The major components causing short life and high maintenance are the engines, transmissions, and rotor blades. A comparison of power requirements between airplanes and helicopters indicates that the life of the engine in helicopters is being reduced because of the great amount of operation at high power. The transmissions consist essentially of gear systems that as such are not new to the customer. The gearing systems and locomotives, trucks, and aircraft engines appear to be no heavier, to operate at no higher speeds, and to have no higher loads than the systems in helicopter transmissions. The life of helicopter transmissions however, is extremely short compared with that of other gear systems. There is no consistency in the design of helicopter transmissions systems when one is compared with another. Rotor blade life varies without reference to size of machine or method of operation. The customer therefore concludes that the short life and high maintenance is the result of inadequate or ineffective engineering design. A solution to the maintenance and availability problem is essential to ensure the future of the helicopter industry and rests squarely with the engineers in the helicopter industry.

Aerodynamics—I

By
W. R. Sears

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This session was devoted to applied aerodynamics and especially to the aerodynamics of wings and bodies. We began the morning with "Effect of Leading-Edge Separation on the Lift of a Delta Wing" by C. E. Brown and W. H. Michael, Jr., of Langley Aeronautical Laboratory, NACA. Rumors of this ingenious and important extension of slender-wing theory have been seeping out of Langley for a year or more. The final product presented here fulfilled expectations.

At reasonably large angles of attack, according to the authors' observations, delta wings produce separated vortex sheets at their leading edges; these roll up as they extend rearward and, of course, have profound effects on the flow about the wing and especially the pressure distribution on the upper surface. The authors have replaced these rolled-up sheets by discrete, concentrated vortices. To determine their positions the familiar Kutta-Joukowski condition of smooth flow is applied at the *leading* edges. Another condition is required, and it is clear that the vortex sheets are carried by the local flow. The question is only how to apply this to the simplified theoretical configuration.

Here an interesting difference of opinion is revealed. Robert Legendre, in France, recently worked out a theory on the lines outlined above and applied the condition that there be no force on the vortex. (He also made an error in computation, which was corrected in the Readers' Forum of the JOURNAL by Mac C. Adams.) Instead of the Legendre-Adams condition, however, Brown and Michaels require zero force on the vortex *plus* the discontinuity surface that connects it to the leading edge. The improvement removes an ambiguity in Mac Adams' results. Brown and Michaels also presented a comparison of their calculated results with measurements on a slender supersonic delta wing.

The audience's interest in this work was obviously great. Professor Nicholas Rott, of Cornell University, presented rather conclusive data in favor of the Brown-Michaels condition as compared with the Legendre-Adams. These were the results of his calculations of shock-wave diffraction around edges—a process that gives rise to a completely analogous curled-up vortex sheet. Dr. H. K. Cheng, of Bell Aircraft Corporation, also presented a slide showing his results for low aspect ratio wings with vortex separation along the side edges.

The second paper, "An Investigation of the Aerodynamics of Sharp Leading-Edge Swept Wings at Low Speeds," by C. E. Pappas and A. E. Kunen, of Republic Aviation Corporation, was on a closely related subject: sweptback wings at low speed, with vortex separation at the leading edges. Without the conical symmetry of the cases discussed earlier, the problem of locating the vortices is more difficult, and these authors have accomplished their objective by a combination of plausible approximations and analysis of experiment. The final results were lift distribution curves calculated by potential-flow theory for the configuration finally arrived at. The Kutta-Joukowsky condition was satisfied at both leading and trailing edges.

A distinguished visitor from overseas, Dr. H. Schlichting, of Braunschweig, contributed to the discussion of the Pappas-Kunen paper. He presented promising results of a new lifting-surface theory developed by Truckenbrodt at Braunsch-

weig, but these pertained to the pure-potential-flow régime, at lower angles of attack than those with which Messrs. Pappas and Kunen were concerned.

Proceeding at this point to the aerodynamics of slender bodies, rather than wings, Howard R. Kelly, of NOTS, Inyokern, spoke on "The Estimation of Normal-Force, Drag, and Pitching-Moment Coefficients for Blunt-Based Bodies of Revolution at Large Angles of Attack." His methods are analogous to those of H. J. Allen but are different in two respects. First, the separated cross-flow field is taken from some rather old tests (by Schwabe) of cylinders accelerated from rest instead of from steady-flow data. Second, the calculation is carried to rather high-order terms in α, the angle of attack.

For supersonic missiles, Mr. Kelly introduces a further refinement—i.e., he uses Milton Van Dyke's second-order results for the potential flow over the nose portion. This is apparently necessary for the large values of α involved in missile dynamics.

The comparison of his results with experiment was indeed impressive. The new theory gives substantially different results from Allen's, and the experimental results presented in the paper fell almost precisely on the new theoretical curves.

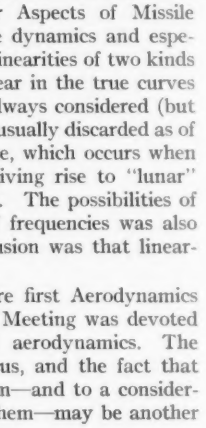
Since at least two of our three speakers had leaned heavily on the work of Dr. Max Munk, who was in our audience, it was a pleasure to hear his remarks after Mr. Kelly's talk. He was pleased to see how far his ideas regarding the aerodynamics of airships—formulated 30 years ago—had been used and extended. He remarked on the philosophy of research in the physical sciences and recommended a clear distinction between theoretical and experimental research, even though both are necessarily guided by the results of each other.

In our final paper of the morning, Messrs. J. C. Crown of United Aircraft Corporation, and S. Fagin, of the Naval Ordnance Laboratory at White Oak, reported on their studies (carried out at NOL) of "Nonlinear Aspects of Missile Motion." This was a study of missile dynamics and especially of spin-stabilized missiles. Nonlinearities of two kinds were included: nonlinearities that appear in the true curves of the forces and moments that are always considered (but usually linearized) and nonlinear terms usually discarded as of second order. An interesting resonance, which occurs when spin and pitch frequencies coincide, giving rise to "lunar" motion of the missile, was pointed out. The possibilities of passing through such a coincidence of frequencies was also analyzed. The authors' general conclusion was that linearized theory must be used with caution.

In retrospect, we see that the entire first Aerodynamics Session of the Twenty-Second Annual Meeting was devoted essentially to some *nonlinearities* of aerodynamics. The nonlinearities have always been with us, and the fact that these four papers were devoted to them—and to a considerable extent succeeded in coping with them—may be another sign of the maturity of our profession.

Aerodynamics—III

By
C. C. Furnas
Director
Cornell Aeronautical Laboratory, Inc.



In the third Aerodynamics Session, four papers, primarily theoretical in nature, were presented. These dealt with secondary flows in cascades, three-dimensional laminar boundary layers with small cross-flow, airfoils oscillating between two walls, and the wake and drag of bluff bodies. Although each of the first three papers presented pertains to several different type problems, one notes that collectively they are of particular interest in regard to current problems dealing with internal flows in turbomachinery.

The first paper, entitled "Secondary Flows in Cascades of Twisted Blades," was written by Dr. Fredric F. Ehrich, of the Advanced Development Section, Aviation Gas Turbine Division, Westinghouse Electric Corporation, and was presented by Dr. Ralph Detra.

Secondary flows in cascades give rise to an "induced pressure drop" somewhat analogous to the induced drag of a single wing. The extent of the secondary flow depends upon the degree of nonuniformity of the approaching stream. Two types of secondary flow can be distinguished. In the first type, the stream is uniform except for a thin boundary layer at the walls. In the second type of flow, the stream is nonuniform over a large part of the span of the blades. Ehrich's paper was concerned with the second type of flow.

Squire and Winter have previously treated the problem of the flow through a cascade of blades whose geometry remains constant along the span and for which the entering velocity profile is nonuniform in the spanwise direction. Tsien, using the classical Prandtl lifting-line analysis, has treated the special case of a cascade of blades whose geometry varies along the span but for which the entering flow is constant in the spanwise direction. Ehrich, using a conceptual model similar to that of Squire and Winter, made a more general analysis for a cascade of blades whose geometry varies along the span and for which the entering velocity profile is nonuniform in the spanwise direction. Ehrich's general analysis reduced exactly to the special form of Squire and Winter and also gave a result quantitatively and qualitatively equivalent to that of Tsien.

Reasonably good agreement was obtained between theoretical and experimental results on the mid portion of the passage between two blades. However, in the experiments, a strong deviation from the analytic result occurred near the cascade walls. Ehrich believes that this is probably due to the growth of a wall boundary layer within the cascades.

Following this paper, Dr. H. Schlichting briefly described some work performed on three-dimensional airfoil cascades at the Institute of Fluid Mechanics, Technical University of Braunschweig, Germany.

The second paper, entitled "Three-Dimensional Laminar Boundary Layer with Small Cross-Flow" was presented by Dr. Artur Mager, Research Fellow in Jet Propulsion at the California Institute of Technology.

Dr. Mager stated that a general treatment of three-dimensional boundary-layer flow is extremely difficult in view of the complexity of the governing differential equations. He pointed out, however, that, for many important problems involving the three-dimensional boundary layer, the flow outside the boundary layer may be resolved into a large principal component and a small crosswise velocity. Since the pressure variation in the direction of the normal to the wall is usually negligible in the boundary layer, it follows that the velocity components in the boundary layer will have the order of magnitude of their values in the external flow. When the crosswise velocity is small compared with the principal velocity, the boundary layer will be only slightly three-dimensional, and the small perturbation procedure will be applicable to a great variety of external flows. Dr. Mager's paper treated three-dimensional laminar boundary-layer flows over flat and sharply curved surfaces subject to these simplifications. His analysis was more general than the usual type of boundary-layer analysis in that it considered flows relative to a coordinate system rotating with a uniform angular velocity.

From Dr. Mager's analysis, it was shown, that to the first order of approximation, the crosswise flow w in the boundary layer is completely independent of the principal flow perturbation w in the boundary layer and is affected only by the gradients of the external flow W and the component of the angular velocity normal to the surface. When the crosswise velocity w is not a function of the z coordinate, the equations for the principal flow perturbation and the crosswise flow perturbations are completely uncoupled.

He presented the results of his analysis as applied to three examples. These were for a spinning circular cylindrical shell flying at a small angle of yaw along a circular path, flow over a flat surface caused by a continuous force field simulating an s-shaped duct, and the flow over a sharp laterally varying concave surface. He stated that, although the accurate determination of the separation point is beyond the scope of the small perturbation analysis which he used, the factors that affect separation are clearly distinguishable. Among these the crosswise variation of the flow was indicated as being important.

The third paper was "Some Considerations of the Air Forces on a Wing Oscillating Between Two Walls for Subsonic Compressible Flow" by D. S. Woolston and H. L. Runyan, Jr., presented by Mr. Woolston. Both authors are from the Dynamic Loads Division, Langley Aeronautical Laboratory, NACA. They presented a procedure for solving the pertinent compressible flow integral equation originally obtained by Runyan and Watkins in *NACA TN 2552*. A collocation method, similar to the procedures of Possio and Frazer for the case of a single airfoil, was used. The approach involved the assumption of an appropriate series expression for the lift distribution, substitution of this series in the given integral equation for the downwash, and the calculation of the downwash at arbitrarily selected points on the chord. In this manner the integral equation was reduced to a set of simultaneous equations, the unknowns of which are the coefficients of the assumed expression for the loading.

A resonant phenomenon, involving a transverse oscillation of the moving air between the walls was discussed. It was shown that at resonance the load on the oscillating wing approached zero, and consequently experimental testing in tunnels should be done under conditions as far removed by resonance as possible.

The authors made numerical calculations to determine the forces on a wing at various Mach Numbers and for various wall heights. The effect of the walls on the lift and the phase angles was shown to be more pronounced as the Mach Number was increased and, at high Mach Numbers, was found to be large even at frequencies well removed from resonance. Increasing the tunnel height greatly diminished the effect of the walls and lowered the resonant frequency.

A few calculations were made at a Mach Number of 0.7 to determine the effect of the tunnel walls on the flutter speed of a simple configuration and to show the effect on flutter of airfoils in cascade. Representative calculations for a wing in a tunnel showed a reduction in flutter speed of about 10 to 15 per cent from the values calculated for free air. For the flutter of airfoils in cascade, at a mass ratio representative of compressor blades, it was found that the effect of the presence of an infinite array of airfoils oscillating 180° out of phase was not very great. However, since the gapchord ratio of 4 used in the example was large compared with the more normal value of unity, the authors recommend further calculations before drawing conclusions.

The last paper, "On the Wake and Drag of Bluff Bodies," was given by Dr. Anatol Roshko, Research Fellow in the Department of Aeronautics at the California Institute of Technology.

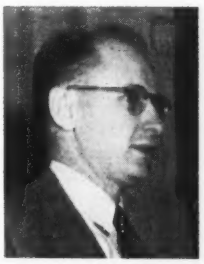
The problem of the drag and shedding frequency in the wake for a two-dimensional bluff body was investigated by Dr. Roshko, with particular emphasis on the region close behind the body. He showed from experiment that the mechanism of vortex formation in this region plays an essential part in establishing the magnitude of the base pressure on a cylinder. The base pressure in turn determines the character of the potential outer flow. Dr. Roshko calculated this potential flow on the basis of a modified Kirchhoff free streamline theory in which the usual circle in the hodograph plane is replaced by a notched circle and the velocity on the free stream line has a value different than that of the uniform stream.

Using this potential theory and some ideas about the vortex formation, he derived a semiempirical theory for the drag. The theory was based on only one empirical fact, instead of the two previously needed, and served to determine the drag not only of the body in question but of bluff bodies of other cross-sectional shapes. In this way a correlation was obtained between bluff body shape, drag, and shedding frequency.

Meteorology

By
H. R. Byers

Professor and Chairman
Department of Meteorology
University of Chicago



Again this year the Institute held a joint session with the American Meteorological Society. The papers dealt with various phases of air motions in the upper atmosphere, particularly above 50,000 ft.

Professor Bernhard Haurwitz, of New York University, opened the discussion with an introduction to the subject of wind measurements at great heights, most of which are obtained by indirect means. He then showed some north-south vertical cross sections which he had prepared from northern hemisphere data showing the zonal—i.e., west-to-east—component of the wind up to a height of 90 km. In winter there is a maximum west wind of 80 m. per sec. at 50 to 55 km. in the vicinity of lat. 30 to 35°N. There is a maximum component from the east of 20 m. per sec. at 30 to 40 km. and 15°N. The same representation for summer gives two maxima of 60 m. per sec. each at 55 km. and 25–30°N. and at 80 to 85 km. at 60°N. The component from the west is about zero at 45–60 km. and 70–80°N. These winds were all computed from the pressure distribution assuming geostrophic balance (pressure gradient force and coriolic force in balance).

At great heights, the speaker pointed out, one must consider electromagnetic and electrodynamic effects on the motions. Also the energy of dissociation and recombination between molecular and atomic oxygen is roughly ten times larger than the release of energy by condensation with which we are familiar in the lower atmosphere. Another effect comes from atmospheric tides which at 100 km. are between 100 and 200 times greater than at the ground. These can account for winds of the order of 30–40 m. per sec.

Dr. Robert D. Fletcher, of the Air Weather Service, U.S. Air Force, gave a paper on "Winds in the Lower Stratosphere." After pointing out how difficult it is to obtain on a routine basis reliable winds in the stratosphere, he showed how contour charts of pressure surfaces in the high atmosphere obtained from the radiosonde networks can be used.

At 25 millibars in January there is a warm area in central Canada and relatively weak winds, but strong winds between that region and the Arctic are apparent from the crowding of the contour lines. All winds are from a westerly direction. In April and October all winds are extremely light, while in

July a flow from the east is indicated over most of North America. On daily charts at 25 millibars many small air circulations are indicated.

From data for 10 millibars, some of it extrapolated from 15 millibars, it is shown that temperature ranges may be extreme—from −60° to −10°C.

Professor Fred L. Whipple, of the Harvard College Observatory, reported on work being done in New Mexico photographing meteor trains to obtain winds in the altitude range from 80 to 110 km.

The corresponding mean wind speed normal to five trains is 38 m. per sec., and the mean velocity 29 m. per sec., in the altitude range from 81 to 113 km. Corresponding total velocities are estimated at 68 and 51 m. per sec., respectively. The winds change rapidly with altitude, showing excursions to more than 100 m. per sec. and average maximum shears of 50 m. per sec. per km. Deviations from the average winds for each train show a zero correlation with winds separated about 5 km. in height (scale height = 6.8 km.), but two show negative correlations for greater height differences to 10 km. or more. A nearly horizontal train shows much smaller wind fluctuations with distance than the others that are highly inclined.

These results suggest tentatively that roughly half the kinetic energy of the high-altitude winds is contained in large-scale systematic motions and the other half in shallow (3–10 km.) eddies, perhaps of the order of 50 km. in horizontal diameter.

The numerical values of the measured winds are in agreement with those obtained by radar-meteor techniques and indicate the validity of these techniques.

The observed wind shears are surprisingly high and demand explanation in terms of energy injection mechanisms.

In a paper entitled: "Atmospheric Motions Inferred from O_2 Dissociation," Dr. Marcel Nicolet, of the Ionospheric Research Laboratory, The Pennsylvania State University, examined the time of dissociation of molecular oxygen in the formation of atomic oxygen. At this time there is a photochemical equilibrium. It is apparent that the number of O_2 molecules is much greater than the photoequilibrium value. This is brought about by vertical mixing of the air in the important transition zone between 100 and 150 km. As a result of this vertical mixing the time of upward diffusion of O_2 molecules is shorter than the time of dissociation. From the computations it appears that the vertical mixing velocity is of the order of 1 m. per sec.

The final paper on the program by Dr. N. C. Gerson, of the Geophysics Research Directorate, Air Force Cambridge Research Center, discussed the winds as indicated by the motion of clouds of ions located in the "E" layer of the ionosphere. These are known as "Sporadic E" and can be traced by the skip reflections they produce on radio-transmitted waves.

Sporadic E, which is located near 110 km., has been studied during the period 1949–1951, inclusive, in cooperation with the Radio Amateurs of North America. These amateurs, operating at a radio frequency of 50 mc. per sec., supplied the basic reports from which the presence, growth, movement, and dissipation of Sporadic E clouds were determined. Usually the trajectory of the moving sporadic area could be delineated. During their movement, many of these clouds grew markedly in size and on some occasions extended over an area of 1,000,000 km.^{2} The drift of the E's areas in the great majority of cases had an easterly component; however, in some instances westerly motions were noted. The average speeds were about 200± km. per hour. It is interesting to note that the average speed is almost the same as that deduced from other sources, including the motions of ionospheric irregularities.

Aeronautical Engineering Education

By
John W. Hoover
Associate Professor
University of Florida

A new addition to the annual meeting was the joint session with the Aeronautical Division of the American Society for Engineering Education held on Wednesday, January 27, with Prof. A. J. Fairbanks, of the Rensselaer Polytechnic Institute, presiding. Sixty persons attended the presentation of papers. This figure included 36 from educational institutions, 12 from industry, and 12 from military, research, or other organizations.

The program included three papers, a short intermission, comments on the papers by two reviewers and open discussion. Strong interest in the discussion was evidenced in the fact that almost all who returned after intermission remained throughout the entire discussion period.

The first paper was entitled "Aeronautical Engineering at the United States Air Force Institute of Technology" and was presented by Dr. B. E. Gatewood, Professor and Head of the Department of Mechanics at the USAF Institute. He stated the mission of the Institute to be the improvement and maintenance at a high level of the scientific, technical, managerial, and other professional competence of Air Force officers. The history of the Institute was briefly outlined, dating back to 1919. The resident program of instruction comprises about one-third of the total enrollment, the balance being in civilian colleges. The policy of the Institute is to emphasize Air Force problems, and the physical arrangement affords an ideal situation and atmosphere for integration of fundamental subject matter with practical Air Force problems.

The Resident College of the Institute of Technology is operated in a manner similar to civilian colleges, using the quarter system and continuing throughout the year. Programs offered include three curricula in Aeronautical Engineering: a 1-year undergraduate program of preparation for graduate school of men with B.S. degrees, a 2-year undergraduate program for students with 2 years of college who meet certain requirements, and an 18-month graduate program for qualified B.S. men. Essential features of the programs are the amount of mathematics given and the broad coverage of the included engineering courses. Subject matter of the various curricula was listed. At present no degrees are granted, though permission is being sought to grant the Master's degree.

A paper entitled "Industry's Requirements for Post-Graduate Education of the Engineer," by Dr. E. W. Conlon, Director of Engineering, and R. L. Graupe, Chief Project Engineer, Development, Fairchild Engine Division, Fairchild Engine and Airplane Corporation, was presented by Mr. Graupe. The paper outlined the need for graduate training for engineers who have been in industry for more than 5 years. Three categories are proposed for such work: a program planned to keep the engineering organization mentally alert and prepared for new development, one for training engineers for promotion to supervisory and managerial positions, and a program planned to give the specialist the opportunity to do advanced work in his field of specialization.

The first program suggests that the proper course of study can better fit the engineer for application of recent advances in technology and science, and the authors believe that industry would profit by sending engineers to a 12-week training course every 5 or 6 years. The second program proposes that early recognition of tendencies toward administration rather than specialization in engineering work would make for greater organizational strength. The third program, on specialization, is one that may closely parallel current graduate

study programs. It is suggested that more faculty employment on a temporary basis by industry would be of mutual advantage. Industry and colleges need to be closely tied together to obtain best solutions of the problem of postgraduate training of experienced engineers, and only through realistic evaluation of all conditions and joint formulation of programs can proper results be obtained.

Dr. Glenn Murphy, Head Professor of Aeronautical Engineering at Iowa State College, presented a summary of the Preliminary Report of the Committee on Evaluation of Engineering Education of the ASEE. The committee's suggestions were given on qualifications, development and evaluation of faculty, the objectives of engineering education and instructional goals, and curricular areas and content.

It was recommended that more material be introduced into the curriculum through one or more of several methods, including increased efficiency of instruction, reduction of duplication, and increased length of time allowed. A suggested division of study programs into professional-general and professional-scientific plans, with increased emphasis on mathematics and science in the latter, was thought desirable. Outlines were given of the minimum fundamental material for such curricula.

Following a brief intermission, comments on each paper were given by Prof. John W. Hoover, of the University of Florida, and Prof. R. Gordon Campbell, of Rensselaer Polytechnic Institute. Open discussion was held after the comments. There was good participation in the discussion. Professors Akerman and Upson, of Minnesota, Hunsaker, of M.I.T., Dutton, of Georgia Institute of Technology, Peery, of The Pennsylvania State University, Rosenberg, of Toledo, Lederer and Woodham, of the Guggenheim Aviation Safety Center at Cornell University, and Andreoli, of Chance Vought, were among those taking part. Topics discussed included possible competition of the USAF Institute with civilian colleges, the considerable need for wider knowledge of available summer industrial employment for faculty, and the problems of teaching environment, student motivation, and faculty evaluation. A concluding note suggested the need for undergraduate industrial scholarships, which might provide more good engineering graduates to industry.

Aircraft Design

By
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The Aircraft Design Session consisted of four excellent papers touching on a variety of topics which, according to the discussions generated, were in fields of considerable interest. The subjects covered included flight-test organization, airplane take-off performance, estimation of wing weights, and flight refueling.

F E. Christofferson, Chief, Experimental Flight Test, Northrop Aircraft, Inc., in his paper "The Flight-Test Organization" made a strong bid for a completely independent status for the flight-test department reporting directly to "top management." The justification for this opinion was derived from a review of flight-test history beginning with World War II. During this early period flight testing was generally found in the aerodynamics department and spent 90 per cent of its time doing stability, control, and performance work. The author claims this launched the period of "modification centers," inasmuch as all "de-bugging" and functional systems testing was left to the operators to eventually overcome and "retro-fit" became an institution.

This form of organization generally gave way to that in common use today, where flight test is a department of engineering and embraces the design interest of all technical and systems groups. The author feels this has resulted in well researched and developed prototypes but overlooks the important aspects of sales potential, manufacturing producibility, and customer satisfaction.

In concluding, Mr. Christofferson believes it is now time to take the final step and place flight test as an independent department in a position under management where it services engineering, sales, and manufacturing from an integrated standpoint and is charged with the objective evaluation of the complete aircraft.

This view was not completely shared by all, and an excellent constructive discussion was finally terminated by lack of time.

Jerome M. Schwarzbach, Flight-Test Division, NATC, Patuxent, presented a paper titled, "A Method of Locating the Airplane Take-off Point and Determining the Take-Off Speed," prepared jointly by Messrs. Schwarzbach, John P. Boston, and Joseph E. Jenkins, all of NATC. The speaker stated that an accurate and simple evaluation of take-off distance and speed is very important in the evaluation of new aircraft, particularly jets and the newer carrier-based designs.

His experience has indicated that various tracking methods and others utilizing on the spot observers are not only expensive from the standpoint of time and man power required but very often are not sufficiently accurate for proper evaluation of the aircraft. This is particularly true on long skimming take-offs where it is difficult to get a sharp indication of being air borne. The method described in his paper has largely eliminated these objections.

Briefly, the system incorporates an accelerometer on each wheel along with a revolution counter. The intelligence is fed into an oscillograph, which is usually aboard for some other purpose. In addition, small asphalt strips are placed across the runway of definite measured intervals near the take-off end. The instrumentation is turned on just before encountering the strips, and if two, preferably three, are crossed, the instrumentation is turned off when air borne and the run is complete. The oscillograph record can be analyzed rapidly and will show a definite trace of each encountered strip and the point of leaving the ground.

Through the use of wheel r.p.m., known distance between the strips and time, a calibration for wheel circumference very near take-off can be made. With an accurate circumference calibration it is a simple matter to get a precise reading of distance and speed at take-off.

Abraham Hyatt, Assistant Director, Research Division, Bureau of Aeronautics, in a paper titled "A Method for Estimating Wing Weights," presented a unique solution to this problem based on a great accumulation of accurate data available from the Navy Bureau of Aeronautics. Mr. Hyatt's method includes as variables the wing geometry, basic flight design weight, ultimate load factor, maximum equivalent sea-level speed, and an equivalent stress factor, f. It is in this factor f that the author develops the latest thinking and experience of the Navy.

Mr. Hyatt pointed out the extreme importance of having a rapid and accurate method of wing weight estimation in the early preliminary design stages of a new aircraft. If conservatism is allowed to creep in during this phase, and it is common for early estimates to play safe, the total airplane weight penalty may compound as much as five to fifteen times the value of the wing conservatism. Very often it is impossible to remove much of this compounded weight even after an accurate final wing weight is determined.

The author pointed out that his value of f reflected the characteristics of over 50 modern aircraft. In view of the compounding weight problem, he strongly recommends using the highest values of f in any category rather than a conservative average of past design practice. Mr. Hyatt feels that by accepting the best available practice as a goal the most diligent effort will be made to refine the structure as the detail engineering progresses.

Lieutenant Colonel Walter P. Maiersperger, Aeronautics Division, Directorate of Research and Development, Headquarters, USAF, in a paper titled, "General Design Aspects of Flight Refueling," presented an interesting and descriptive integration of flight refueling history, development, and operating problems based on extensive actual experience. See page 52, March REVIEW, for his full paper.

Lieutenant Colonel Maiersperger's paper was followed by an excellent moving picture illustrating the early refueling flights and modern systems.

Motorless Flight

By
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The Motorless Flight Session presented thoughts on a means for economical towing of gliders aloft, an analysis of the aerodynamic drag of airplanes, and how to determine the true vertical motions of the air with a glider. These topics must have been of real value to many people to judge from the interest evident in the room full of people.

The problem that Robert C. Kidder, of the Flight Research Department of Cornell Aeronautical Laboratory, Inc., tackled in his paper "Design Studies for the Evolution of an Economical Towplane," results from the not too gradual elimination of the surplus Stearman and Waco biplane primary trainer types. As a consequence the price of these towplanes has been increasing and spare parts have become scarce.

Kidder centered his entire study of a suitable towplane replacement around the Piper J3C Cub and investigated four configurations for possible use. The first study consists of two J3C fuselages each with a 65 hp. engine, joined so that their fuselage centerlines are approximately 7 ft. apart.

This design was considered for the following reasons: (1) a total of 130 b.hp. with the reliability of two engine operation; (2) high propeller efficiency (72 per cent) (even though standard approved parts were used, the CAA took a dim view of this and so the idea died).

This limited the thinking to single fuselage. Two configurations suggested themselves in the attempt to improve propulsive efficiency, one with a very large propeller driven through a V-belt and another—the same aircraft with two propellers mounted 3.5 ft. either side of the engine centerline. However, the cost of obtaining a type certificate does not appear to justify the changes.

This setback forced a critical examination of the standard J3C certificated for a Continental C90-8F engine and a metal propeller of 71 in. using a Clark Y blade section. The direct drive installation, while not a phenomenal performer, does exceed the minimum design requirements for a towplane. There is no problem in licensing this aircraft and so the J3C-90 Piper Cub is one answer to the problem of replacing our vanishing Stearmans and Wacos.

The discussion was sparked by Capt. R. S. Barnaby (USN, Ret.), who inquired whether the CAA is reluctant to permit towing with cabin airplanes. To this Kidder replied that any such restriction is purely a local thought and not of the CAA. The cudgel was taken up by F. P. Bundy, of General Electric Company, who asked whether the mass ratio of the towplane-glider was considered from the turbulence angle. The speaker replied that with a light towplane the line is taut and minimizes the effect of turbulence.

Walter Setz, of the NADC, Johnsville, Pa., observed that attaching the line to the c.g. point would help the towplane and said that thought should be given to recovery of the rope in flight on a permanent reel in the towplane. August Raspet confirmed Kidder's performance computations by quoting a measurement made on a Super Cub 125.

In the paper "Application of Sailplane Performance Analysis to Airplanes," August Raspet, Aerophysics Department, Mississippi State College, described the technique of using full-scale flight measurements as a means for investigating the quality of the airflow around an aircraft. These measurements can serve a twofold purpose: (1) to reveal to the designer how closely the final product approaches the performance computations; and (2) as a gage to judge the execution of the design by the craftsmen.

The procedure for a drag polar determination of an airplane is to remove the propeller and substitute a glider release by which the airplane is towed to 10,000 ft. and then glides down. On large airplanes the climb is under the plane's own power; then the engines are stopped and propellers feathered. The total drag is obtained by a measurement of rate of loss of potential energy—i.e., altitude. Errors that would be due to turbulence are reduced to negligible quantities by conducting such tests in the still air of dawn.

The data obtained from power on and from glide measurements are reduced to the linearized drag polars, C_L^2 vs. C_D, and one is able to separate such performance parameters as minimum drag coefficient and the Oswald efficiency factor, the overall propulsive efficiency, the cooling drag, and indications of boundary layer separation. Separation or a rapid growth in the boundary layer results in a rapidly rising drag.

The selection of an airfoil is nullified by inattention to production methods wherein rivets, seams, and gaps on the leading edges will cause a transition from a laminar to a turbulent boundary layer. To determine the profile skin friction is not too difficult using the integrating wake rake technique developed by Doetsch. To investigate the nature of the flow over a wing, there is now the simple process of spraying on a solution of naphthalene in petroleum ether. In flight, at the desired lift coefficient, the film sublimes from regions where the flow is turbulent and remains where the flow is laminar. Another technique is to use a stethoscope with a small pitot at the end of a long tube. When the pitot probe is placed in a laminar flow a hiss is heard, but, when in a turbulent flow, a loud frying noise is heard.

Tests such as these reveal that the minimum skin friction is much more than the full turbulent flat plate because of areas of separated flow and regions of accelerated flow where the skin friction is higher than on a flat plate. The technique of measurement, diagnosis, and prescription of modifications was applied to the sailplane RJ-5. This world distance record holding sailplane was brought from a mediocre glide ratio of 29 to the present one of 40.

A principal conclusion is that current emphasis on airfoil selection might better be realigned to an effort to maintain the leading edges of the production airplanes, wave free and to eliminate zones of separated flow.

The discussion was initiated by Capt. R. S. Barnaby, who asked whether the flush smooth wing will lose its effect unless it is polished before each flight and will there be any performance gain left if the wing is left dirty. Raspet affirmed that the residue of performance gain would still make it worth while to have a super smooth wing, though dirty. In any case we

might get the equivalent of windshield service in gas stations wherein airport attendants will wipe off wings with each purchase of gas. A. Lipstein, of Schenectady, inquired if the laminar separation point on the leading edge would set the point of transition even after the wing is made smooth. The author replied that laminar airfoils are intended to move the laminar separation point far back but that in the wing and fuselage intersection transition occurs early on the upper surface and that the logical way to avoid this is to reduce the number of intersections and to use high wing designs.

R. Griswold, USAF, questioned the economical value to air lines of smoothing the wings with putty. Raspet was positive that the saving in fuel would more than pay air lines for the task of smoothing the wings and remarked that in the B.O.A.C. Comet it would be more economical to remove the windows and substitute floor shows for entertainment in lieu of an outward view. To a remark by Raspet that a pusher propeller would permit a larger laminar extent on the wing and fuselage, T. O. McClure, of RCA, observed that, in the pusher type of airplane and in the helicopters, vibration is developed because the blades operate in the turbulent air. Raspet responded that boundary-layer control by suction should eliminate the low energy wake through which the propeller passes and which results in vibration of the propeller.

In the paper, "Measurement of Vertical Motions from a Glider," Paul B. MacCready, Jr., Consultant in Meteorology, discussed rising awareness of the importance of upcurrents in the day-to-day type of flying, whether just for fun or for the avoidance of turbulence or to stretch the gasoline dollar and, of course, for safety in mountain flying. The glider pilot who is always hunting for these invisible upcurrents uses a sensitive rate of climb indicator called a variometer.

A variometer is essentially an altimeter with a leak that tends to make it read the altitude *relative* to the altitude a moment earlier. The indication of the rate of climb comes from the measurement of the rate of airflow. Unfortunately, zooms and dives also indicate on the instrument as though the glider is in an updraft or a downdraft.

The sailplane pilot is more interested in what the air is doing than in what the sailplane is doing, and by connecting the variometer to a special venturi, the air-speed changes, due to "stick" thermals, will be included in the most desirable way. In still air, with this arrangement properly coordinated, the pilot cannot cause the variometer to budge from zero—even if he zooms or loops. Such an arrangement is called a total energy variometer.

The rate of change of total energy is due to the altitude change (potential energy) plus the air-speed change (kinetic energy) and the air speed (dissipation due to drag). When the variometer is connected to the venturi the reading shows the rate of change of total glider energy, potential plus kinetic.

The total energy variometer has its greatest use when the pilot is flying at high speeds and is trying to estimate the lift available in thermals he passes through. Without the venturi, "stick thermals" tend to hide true thermals. The average effective cross country speed of a glider is increased approximately 5 per cent by the use of the venturi.

Unfortunately, the simplest venturis are so greatly affected by yaw as to be unusable, so a venturi was devised which is practically unaffected by yaw. It has a plate at the downstream end which serves to keep the exit pressure constant despite yaw.

The total energy variometer will respond to air velocity changes, as well as glider velocity changes, since it is concerned only with the relative motion between glider and air. Thus it does not perfectly separate vertical from horizontal air motions.

If it were possible to add the sinking speed of the sailplane as a function of air speed to the variometer, the variometer would show very closely the exact vertical air motions. The slight error introduced when the glider is subjected to G loads, which changes the performance curve of the glider, could be completely ignored. The air-speed correction can be introduced by connecting a pitot tube (which measures the total dynamic pressure) to the tube that runs from the air chamber to the variometer. In this tube add one or more needle valves to act as an adjustable air resistance, such that it is 20 times the air resistance of the variometer. Thus there is a steady flow through the variometer which is proportional to the air speed squared and will cancel out the normal sinking speed.

Another improvement in variometers is to make the indication audible. The Temple variometer shows up and down by flashing lights and should be a simple one to convert to some type of buzzer indication. Such a variometer, plus the French Badin model and also the Aircraft Indicator Company variometer, should be on the instrument panel of every sailplane.

In the discussion Raspet pointed out that the originator of the total energy variometer was A. Kantrowitz, then of NACA now of Cornell University. In a Letter to the Editor (JOURNAL OF THE AERONAUTICAL SCIENCES, 1940, page 523), Kantrowitz derived the theory and coined the name "total energy variometer."

Commander H. C. N. Goodhart, of the British Royal Navy, made a plea for a static connection to reduce the icing difficulties attendant to the pitot suggested by MacCready for the correction of sinking speed variation of the sailplane. To this MacCready countered that, ideally, one wishes a higher power variation of pressure with speed than even the parabolic provided by a pitot tube. A cubic variation should permit exact compensation at the higher speeds. Setz reiterated the icing difficulties suggesting a flush pitot such as used on most modern sailplanes. To Bundy's query about the behavior of a total energy variometer in turbulent air, both MacCready and Barnaby replied that most instrument indications except that of the long period averaging types are of academic interest only.

To the old dream of sailplanists to be able to see thermals brought up by Stanley Smith, of Bell Aircraft, Karl Lange, of the University of Kentucky, known for his pioneer work in up-current research, replied that his studies indicate that the buoyancy of a parcel of air in a thermal is as much due to humidity as it is due to a temperature difference. The very small temperature differences measured by Raspet in 1938 with the temperature gradiometers bear out this fact. Also Lange had a strong argument in having traced upcurrents to swamps in many cases he studied. Smith pointed out furthermore that modern infrared and radar technology should be considered for visualizing upcurrents. The sharpness of the interface was mentioned as a consideration by Bundy.

These papers covered areas in the field of aviation of great interest to those who fly without power. Yet the ideas presented may well prove applicable to all phases of aviation. To judge from the roster of those who attended, this session, which was devoted to motorless flight, appealed to a representative cross section of the aviation world.

Aerodynamics—IV

By
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The Johns Hopkins University

The fourth session on Aerodynamics was a joint session held in cooperation with the American Physical Society. Both societies hold their annual meetings during the same week in

New York. It was a pleasure to bring together members from the two societies to hear a set of papers of mutual interest.

The first paper of the session, "Aerodynamics of Blasts: Diffraction of Blast Around Finite Corners," was presented by Prof. J. F. Ludloff, Guggenheim School of Aeronautics, New York University. The co-author, Dr. M. B. Friedman joined in the discussion. The problem had its origin in studies undertaken during the war to determine what happens when shock waves are diffracted by obstacles they strike. The simple case of a plane wave striking an inclined plane was studied in detail and it was found that discrepancies with theory occurred when the reflection was of the Mach type with three waves coming together at a point in the gas. To understand this phenomenon, several authors attacked the problem using various linearizations assuming the disturbance field was small. Ludloff and Friedman have successfully solved the problem when the disturbance is not small.

They have done this in two ways. First, they have used a set of conically expanding coordinates in which the problem is elliptic with unknown boundaries. Second, the problem was treated as a hyperbolic problem in which the field grows with the time. In both cases the problem is solved numerically. Considerable attention is devoted to the behavior of the fluid around the point which was at the vertex of the corner when the shock struck the corner. There was considerable discussion after the lecture of the authors' statement that the numerical difference scheme treats correctly the jumps in entropy that occur across the finite lattice points.

The second paper was entitled "Pseudo-Transonic Similitude and First-Order Wave Structure." It was by Dr. Wallace D. Hayes, Scientific Liaison Officer, Office of Naval Research, London.

In obtaining the simplication necessary for the linearized solutions of compressible flows, it is necessary to neglect the variations in wave structure that immediately strike the eye when one looks at any picture of a compressible flow. Dr. Hayes has examined the second-order terms that give these first-order changes in wave structure at some distance from the body.

The important ones are those that are cumulative in their action, and he has been able to separate these out. He finds that these effects exhibit a similitude that is quite analogous to the transonic similitude introduced by von Kármán.

By using these ideas, Dr. Hayes is able to express in understandable terms many of the interesting features of wave systems that cause difficulty because of the nonlinearity of the equations.

The third paper was a "Summary of Recent GALCIT Hypersonic Experimental Investigations" by Dr. Henry T. Nagamatsu, Director, Hypersonic Wind Tunnel, California Institute of Technology. In hypersonic flows, the ratio of the temperature of the free-stream air to the temperature of the air in contact with any solid surface exposed to the flow is so great that it causes difficulty both in flight and in the wind tunnel. In flight, the free-stream air is at a reasonable temperature, but the surface temperature soars to staggering values. In wind tunnels, the ratio works the other way around. Surface temperatures are in the usual range of experience, but free-stream temperatures fall to such low values that the experimenter is plagued with liquefaction of the air.

In the GALCIT 5- by 5-in. tunnel, measurements were made to determine the conditions under which condensation takes place. Dry air, free of carbon dioxide, was found to undergo considerable supersaturation before condensing. Both water vapor and carbon dioxide prevented any appreciable amount of such supersaturation. Heaters have been installed to prevent condensation in the working range of the tunnel.

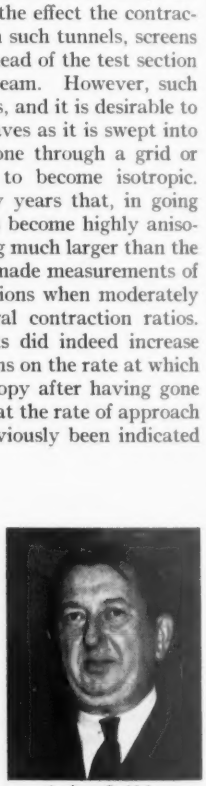
A large number of conventional experiments in supersonic flows were done in the hypersonic stream. These included heat-transfer and stagnation temperature experiments on a cooled flat plate and on cones. Also, direct measurements were made of laminar skin friction using a small plate mounted in the wall on a balance. It was found that, at hypersonic Mach Numbers, the laminar flow was surprisingly stable to strong disturbances introduced into the flow. The boundary layer was also found to have a strong interaction with the shock wave that lies very close to the boundary layer in hypersonic flows. This interaction causes a pressure gradient to be produced on the front portion of the plate. Dr. Nagamatsu also gave a brief description of a hypersonic shock tube that he and his colleagues have developed.

The last paper of the session was by Dr. Mahinder S. Uberoi, of the University of Michigan, and was entitled "Effect of Wind Tunnel Contraction on Free-Stream Turbulence."

Since the advent of the low-turbulence wind tunnel, considerable interest has developed about the effect the contraction has on free-stream turbulence. In such tunnels, screens are provided in the settling chamber ahead of the test section to damp out the turbulence of the stream. However, such screens never damp out all of the eddies, and it is desirable to know how the residual turbulence behaves as it is swept into the test section. After the air has gone through a grid or screen, the turbulence tends slowly to become isotropic. However it has been known for many years that, in going through a contraction, the fluctuations become highly anisotropic, the lateral components becoming much larger than the longitudinal component. Dr. Uberoi made measurements of the changes that occur in the fluctuations when moderately strong turbulence goes through several contraction ratios. He found that the lateral components did indeed increase several fold. He also made observations on the rate at which the turbulence again approached isotropy after having gone through the contraction. He found that the rate of approach was considerably slower than had previously been indicated by MacPhail.

Rocket Propulsion

By
James J. Harford
Secretary, ARS
for
Chairman
Andrew G. Haley
President, ARS



Andrew G. Haley

In the first paper "Ballistics of an Evaporating Droplet" by C. C. Miesse, of Aerojet-General Corporation, the author analyzes the behavior of droplets—particularly fuel droplets injected upstream in a ram-jet burner—taking into account the droplet velocity and size, air velocity, and physical properties of the surrounding air. The analysis is based on the assumptions that (1) the drag coefficient varies inversely with the Reynolds Number; (2) the surface area of the droplet varies linearly with time; (3) the velocity of the surrounding gases varies linearly with distance.

The analysis, of potential value to those concerned with combustion-chamber design, concludes that maximum droplet diameter—if droplet is to evaporate completely—varies inversely with the square root of its evaporation rate. Also, it appears that, even though gas velocity affects evaporation rate, droplet evaporation takes place in conformity with the same laws describing evaporation in still air. The study also shows that it is possible to determine analytically the velocity profile of an evaporating droplet, the velocity of which varies linearly with distance, and it proves that the approxi-

mation of a curved air-velocity profile by a series of straight lines instead of by a single chord is not warranted except in extreme cases.

The second paper, "Gas Torch Igniters for Rocket Motors" by George N. Woodruff, of Reaction Motors, Inc., describes an ignition system that uses a separate supply of propellant to create a high-temperature flame for igniting the main body of rocket propellants. This system is opposed to the conventional pilot ignition system, which by-passes a portion of the main propellants to an ignition element. Experimented with because of its promise for greater reliability, the gas torch system also makes possible a wider selection of propellant combinations as igniters, permits removal of the igniting element from the operating region of the rocket motor, and affords information that can be applied to liquid propellant igniters as well as gaseous igniters.

Hydrogen and oxygen were the gases used principally in the tests because of the clean combustion they produce. Several different ignition elements were tested and an electric spark system selected as most practical. Various designs of gas-bleed surface-gap spark plugs were developed. They have been applied successfully to rocket engines over a wide range of thrusts at Reaction Motors, Inc., according to Mr. Woodruff.

The paper "Toxicity and Health Hazards of Rocket Propellants" was presented by Stephen Krop, of the Army Chemical Center in Maryland. In many cases rocket fuels and oxidizers and their decomposition products present serious conditions of toxicity to handlers. Mr. Krop analyzed the characteristics of some of the leading fuels, including ammonia, aniline, ethyl, methyl and furfuryl alcohol, hydrazine, JP-4, hydrogen peroxide, liquid oxygen, and red fuming nitric acid.

In "Lightweight Electric Analog Computer with No Moving Parts" by Dr. Paul H. Savet, of Arma Corporation, the computer was developed principally for applications in navigation and piloting of aircraft and guided missiles. It performs basic calculus operations directly on a.c. electric signals and multiplies and divides statically by means of heat transfer, thus eliminating the need for servomechanisms, according to Dr. Savet.

It is, essentially, a transducer that dissipates an incoming electrical signal into heat. Output of the transducer is determined by the unbalance in a Wheatstone bridge to which the temperature differential has been communicated.

Flight Safety

By
Jerome Lederer
Director
Flight Safety Foundation, Inc.

for
Chairman
T. P. Wright
Vice-President of Research
Cornell University

T. P. Wright

The Institute of Aeronautical Sciences deserves praise and thanks from students of air safety for providing each year since 1951, in a crowded week of technical sessions, a session devoted entirely to air safety and billed as such. This has had the extraordinary effect of giving respectability to air safety as a separate branch of aviation. Air safety is now discussed openly instead of out of one corner of the mouth. These air safety sessions have always attracted a good attendance and have provided interesting and occasionally humorous discussion.

In 1954 the first paper was presented by J. N. Pecoraro, who heads the Air Applications Branch, Special Devices Center of the ONR and was recently awarded the Arthur Williams Fellowship by the American Museum of Safety. He discussed the use of simulators as a research tool in "The Use of an Operational Flight Trainer as a Research Tool for Aircraft Instrumentation and Cockpit Rearrangement."

The data necessary for the analysis was obtained from interviews with pilots, observation of pilot activity during flight, and study of pertinent literature.

The report states the problems and requirements for establishing a simulation program. It presents the methodology and equipment (Operational Flight Trainer) for evaluating the various practical configurations and outlines the experimental program for their assessment.

A summary of conclusions drawn from this program to date are: (1) The cost of the program averaged $10,000 to $12,000 per instrument. (2) A new source of "empirical data" is available for engineers and instrument designers, particularly data on training savings on instrumentation based on new instrument displays. (3) A means is also available for improving operating procedures through simulation of equipment systems. (4) Since subjective appraisal is still a service requirement, the ultimate would be objective scoring, where possible, in actual flight.

Among the many questions asked was one that added to Mr. Pecoraro's paper by suggesting that when pilots use this research tool their proficiency be compared with established learning curves.

Carl Christenson, Director of Safety, United Air Lines, Inc., presented the most comprehensive and effective paper ever given on the economic aspects of safety, "Management's Economic Interest in Safety." It covered more than passenger safety however, inasmuch as it also discussed such topics as cost of mishaps on the ground. A more appropriate title might have been "Management's Economic Interest in Loss Prevention," because his paper was all inclusive.

Christenson started by stating the philosophy behind management's economic interest in safety: "It is fortunate that the social concern for human life and the economic concern for the protection of both life and property are such that, when either one is provided for, the other is simultaneously and automatically cared for. Regardless of the motives involved therefor, whether they be humanitarian, economic, or blends and variations of each, consideration for the safety of operation is an essential element of good business, and its cost is more easily sustained than the price paid for the lack of it . . . . This economic interest springs primarily from three basic factors: (1) the creation of confidence in the minds of the traveling public; (2) the increasing efficiency in production and dependability in flight operations; and (3) the decrease in cost of operation."

Christenson divided his paper into personnel accidents, equipment damage, tolerated abuse, and flight accidents.

A hypothetical air line with 15,000 employees should expect 2,000 personnel accidents or injuries each year, costing $700,000!

Equipment damage, such as minor damage caused by the tail cone of one airplane coming in contact with the wing tip of another, would cost possibly less than $100 for repair of both aircraft, including labor. But the cancellations of two trips, equipment substitutions, ferrying, etc., creates indirect losses which in the case of an air line involved in 300,000 operations per year will amount to between $600,000 and $900,000! Highly congested airports make this problem more acute.

Tolerated abuse, such as punctured holes caused by dropping fuel nozzles or by fork lift trucks, add another million dollars per year!

On top of these ground losses are in-flight accidents involving safety to passengers and crew with modern equipment. This is estimated at $5,000,000 per accident, the intangible losses due to repercussions following the accident not being included.

In addition, there are flight losses resulting from major mishaps such as nose gear collapse. The total costs of these vary from $200,000 to $500,000 per year. Captain Christenson concludes that, aside from humanitarian reasons, safety is "vitally important to sound business practice."

R. W. Rummel, Chief Engineer, Trans World Airlines, Inc., then followed with a design bible that showed how some of Captain Christenson's losses might be reduced. He began with a well-deserved tribute to designers and then suggested several principles for producing safer aircraft: (1) design to prevent the transmission of inaccurate or misleading information to the flight crews such as false fire warnings; (2) provide simple means for the pilot to cope with emergency situations, such as a gang switch to cut out a multitude of electrical circuits; (3) simplicity of design to reduce manufacturing costs, avoid operational delays, ease trouble shooting; (4) learn more about ourselves as a human machine and use this knowledge as a design parameter; (5) use more extensively mock-ups and prototype design testing in development stage of design; (6) provide a maximum of system segregation such as isolating fuel plumbing from ignition sources; (7) use materials and load factors that would increase structural reliability, especially to provide greater assurance against fatigue failures; (8) provide crashworthiness, including emergency evacuation, to the greatest extent possible without losing sight of the primary objective of minimizing the causes of trouble. He emphasized the importance of keeping draftsmen, detailers, and designers fully informed with respect to service experience. He ended with "we must proudly protect (our excellent safety record) at all times and constantly strive to improve in the future . . . by constant review of past operating experience coupled with continuing and expanding research activities."

Erratum

Fig. 2 of the article "The World's Largest Wind Tunnel" by W. J. Walker, appearing in the March issue of the *Review*, was incorrectly reproduced. The following figure should be substituted.

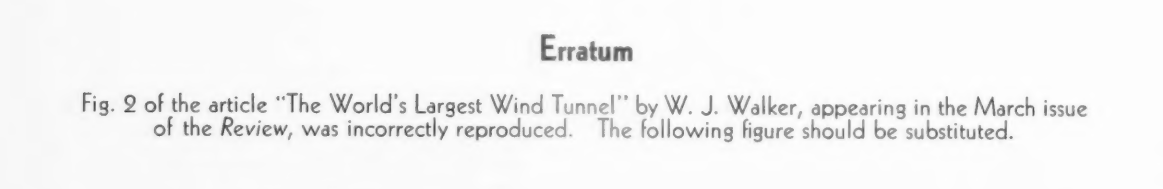


FIG. 2. Schematic drawing of the transonic compressor, the drive motors, and the supersonic compressors. A simplified electrical diagram for one set of motors is shown. At the right in this diagram is the d.c. braking arrangement. In the supersonic compressor circuit, one iris valve is shown in a by-passing position.

Personnel Training Required to Produce Large Quantities of High-Performance Aircraft

LEVERETT P. WENK*

Republic Aviation Corporation

IN LESS THAN A DECADE, the aviation industry has been called upon twice to train innumerable thousands of personnel in order to build the mighty air forces that rained destruction on our enemies and protected our ground and Naval forces. To build these air forces, our air-frame, engine, and component parts manufacturers undertook the tremendous job of training unskilled personnel in the various skills and knowledge required not only to construct aircraft but to engineer them.

During World War II, a desire to help our Armed Forces filled the hearts and minds of all our citizens on the home front. Many applicants clamored at the gates of our aircraft manufacturers for jobs, and when the flow of applicants decreased, a patriotic appeal to neighboring communities brought large numbers of new applicants.

After the cessation of hostilities in 1945, we all watched the various aircraft manufacturers lay off not only thousands upon thousands of employees who had been so laboriously trained to build the mighty air armada we had during the war but also the lower echelons of management who supervised these employees. At the outbreak of the Korean conflict, the air-frame and component parts manufacturers in this country employed only a small fraction of the number of people they had had at the height of World War II.

Russia and the countries behind the Iron Curtain, we found, had not only continued their production of military aircraft but had kept their own designers, and the designers in the countries behind the Iron Curtain they had taken under their influence, busy designing newer, faster, and better planes for aerial combat. Thus, this country found itself lagging in the manufacture of newer types of aircraft when the Korean War began. It therefore became necessary for the aircraft industry again to train more thousands of workers to build in ever-increasing quantities the finest air-borne implements to fight our new enemy—Communism.

Because the Korean conflict was only a "police action" on the part of the United Nations, the all-out effort was not there to draw personnel into so-called defense industries. It was also a period of relatively full national employment, and without the impetus of an all-out war, it took ingenuity and perseverance to channel workers into a defense industry. The large majority of those who had been laid off at the close of World War II had found jobs in civilian industries that offered them, to their way of thinking, greater job security. They had no desire, and still have no desire, to return to an industry that has had as many economic peaks and valleys as does the aircraft industry.

This problem of recruitment has been met in many ways. For a time in the beginning, it degenerated into an almost "dog eat dog" cycle. Skilled personnel were bartered for by various, and sometimes devious, means. We can thank each other that this pirating has now ceased.

Many companies, in order to make the fullest possible use of sources of new man power, restudied the physical and mental requirements of their various jobs and were able to reduce to the lowest possible rate the medical rejection of job applicants. In one company, 28 per cent of new applicants could not, because of minor deficiencies discovered in employment examinations by the medical department, be certified for work on all jobs. However, rather than reject them, this company carefully screened them for jobs they could do. While these persons now do work that their deficiencies do not affect adversely, this utilization has put an added administrative load on the company, but this added effort has enabled them to use sources that could not otherwise have been used.

I do not for a minute want to give you the impression that I feel that man-power problems have been licked. For example, more than 600 design and application engineers are now working in a single engine plant. Although unprecedented numbers of engineers are working today to design, develop, and produce the high-performance airplanes needed for America's fighting forces, there are still, as we all know, not enough engineers to meet the demands. As the military forces have called upon the U.S. aircraft manufacturing industry for planes that fly higher, farther, and faster with consistently increasing dependability and fire power, the need for engineers has skyrocketed. Today, between 50,000 and 60,000 engineers are at work in air-frame, engine, and component plants throughout the nation. In addition, uncounted thousands of engineers are at work in plants of more than 61,000 subcontractors and suppliers of the industry.

To fill the growing need for aeronautical engineers, plus that of the rest of American industry, it has been estimated that a minimum of 30,000 engineers should be graduated from U.S. schools each year.

Presented at the Electronics Session, Twenty-Second Annual Meeting, IAS, New York, January 25–29, 1954.

* Director of Training.

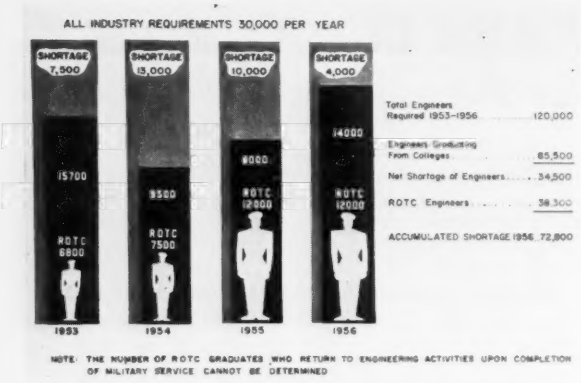


FIG. 1. Engineer requirements vs. college graduates.

Fig. 1 shows that the minimum total number of engineers required for the years 1953 through 1956 is a total of 120,000. Engineers graduating and scheduled to graduate from colleges during these years total 85,500, giving a net shortage of 34,500. In addition to this shortage, 38,300 of the engineers now attending engineering schools are members of the Reserve Officer Training Corps. The number of these ROTC graduates who will return to engineering activities upon completion of military service cannot be determined. Many will no doubt stay in the Armed Forces. What then must the aircraft industry do to acquire its portion of the accumulated shortage of approximately 72,800 engineers by 1956? Compare this with what excellent sources of information have said when they stated that Russia is today training at least 100,000 engineers each year.

Today, despite the fact that aeronautical science is at perhaps its most spectacular stage, aviation careers appear to have lost the interest of a large portion of American youth.

For this reason, the success of widespread aviation education programs, aimed at placing in perspective the startling aeronautical advances and revolutionary changes of the first 50 years of powered flight, has never been more important.

Such programs are already under way on several fronts, sponsored by such groups as the National Aviation Education Council, the Civil Aeronautics Administration, the Civil Air Patrol, the Air Force, the Navy, the air-line industry, the aircraft industry, and others.

Leading national educators have undertaken, through the National Aviation Education Council and with the support of the Aircraft Industries Association, to prepare materials for the use of schools throughout the country.

Such active programs are long overdue—at a time when man's wings have changed the pace of the world, the concepts of commerce, and the tempo of communications.

Today, to help combat this shortage, a number of aircraft manufacturers are providing engineering education for their draftsmen and junior engineers, helping them, through financial aid, to attend local engineering schools during their off-duty hours. One school serving the aircraft industry on Long Island is providing, during evening hours, complete engineering courses in aeronautical engineering, mechanical engineering, and electrical engineering which may be completed in 6 years. These courses are being conducted at Adelphi College in conjunction with New York University. During the first 3 years, professors from N.Y.U. are coming to the Adelphi campus in order to minimize traveling difficulties for those students who attend the course. During the last 3 years, when laboratory work will be required in N.Y.U.'s Guggenheim School of Aeronautics laboratories, bus transportation will be provided from the Adelphi campus to the New York University campus and return.

In addition to this course, high-school principals in various Long Island communities have been asked to recommend outstanding students who, because of financial difficulties, are unable to pursue higher education in engineering. These young men are being hired by various Long Island aircraft industries as junior draftsmen on a 30-hour week. Working 6 hours per day, they are able to leave their plants early in the afternoon, attend classes, and still have adequate rest. Tuition for these courses is being paid by the individual participants. Upon successful completion of each term, 50 per cent of the tuition is refunded by the employer. If the student successfully completes the entire 6-year course, the other half of the tuition is refunded by his employer.

Many people not associated with the aircraft industry wonder why it requires so many more engineers today

AERONAUTICAL ENGINEERING

Weights
Research
Flight Test
Structures
Aerodynamics
Design

MECHANICAL ENGINEERING

Weights - Structural Major
Research - Those graduates with Thermodynamic Major and/or Fluids (not Stationary Power Plant)
Structures - Structural Major
Design
Thermodynamics

CIVIL ENGINEERING

Weights
Research
Structures
Design

ELECTRICAL ENGINEERING

Research - Radio-Electronics Major (not Power)
Design

FIG. 2. Assignment of engineers to Engineering Department, Republic Aviation Corporation.

TRAINING ASSIGNMENTS USUALLY CONSIST OF 6 WEEKS DESIGN AND 2 SESSIONS OF 9 WEEKS EACH WITH TECHNICAL SECTIONS

	DESIGN 6 Weeks	1st TECH. SESSION 9 Weeks	2nd TECH. SESSION 9 Weeks
DESIGN *			
Electrical	Yes	Stress	No
Structural	Yes	Stress	Stress (Optional)
Other	Yes	Stress	Stress (Optional)
AERODYNAMICS	Yes	Aerodynamics	Thermodynamics Flight Test Research
FLIGHT TEST	Yes	Flight Test	Aerodynamics Research Thermodynamics
RESEARCH			
Instrumentation	Yes	Stress	No
Electronic Test	Yes	Stress	No
Structural Research	Yes	Research	Stress
Functional	Yes	Research	Stress
P.P. & Heat Transfer	Yes	Research	Thermodynamics
Static Test	Yes	Research	Stress
Control Systems	Yes	Research	Stress
STRUCTURES	Yes	Stress	Research Aerodynamics
THERMODYNAMICS	Yes	Thermodynamics	Aerodynamics Flight Test Research
WEIGHTS	Yes	Weights	Stress

* Design trainees are also expected to spend 2 additional weeks in Loft Engineering training.

FIG. 3. Six-month engineering training program sponsored by Republic Aviation Corporation.

than it did in World War II. It would no doubt be of interest to them to know that a typical modern fighter, for example, requires 27 times as many engineering hours as its World War II counterpart.

In order to utilize recent college graduates holding nonaeronautical engineering degrees, Republic Aviation Corporation developed a 6-month transitional training program for mechanical, civil, and electrical engineers. Engineers with these degrees are assigned to the various engineering sections shown on Fig. 2.

Dependent upon needs and abilities, engineers so recruited may elect assignment to the engineering section they desire. Once the assignment has been made, the program shown in Fig. 3 is pursued.

These various training assignments are on a rotational basis wherein the trainee is required to perform selected engineering work under the help and guidance of group leaders.

Fig. 4 shows the number of different kinds of specialists, all having varied skills, who are required to build a single aircraft today. Figures have been secured from a manufacturer who has built more fighter-bomber aircraft than any other manufacturer in the Free World. In addition to the 38 different engineering classifications required to design and engineer the aircraft, it requires an additional 138 different classifications of technicians to build it. Indirect labor required to support these engineering and direct labor technicians covers 143 additional different classifications. This gives a total of 319 different skills required. Many of these skills have three to six grades.

Fig. 4 graphically portrays the variety of skills needed to build a single jet power plant. This power plant requires 8,854 separate parts and 87 different kinds of specialists to create it. The 87 types of specialists, all highly trained in their professions and trades, perform several thousand different engineering and precision manufacturing jobs. And behind the direct engine production workers are hundreds of other specialists employed by subcontractors and suppliers to produce many of the jet power plant's 8,000 plus parts.

Some help in providing technicians for the aviation industry comes from the various technical schools and institutions throughout the country, of which there are 67 in number. The ninth annual Survey of Technical Institutes, released last November, states that during 1952, there were graduated some 3,323 people who had followed curriculums in electrical technology. Of these, 2,591 specialized in some phase of electronics training. Mechanical technology ranked second with 1,605 graduates, and aeronautics ranked third with 852. This was a decrease of some 4.6 per cent when compared with the number reported in 1951. From this relatively small number, I am sure you will agree that, if we want technicians, we are going to have to train them ourselves.

As an example of this type of training, a formal program for the training of Methods Analysts was developed at Republic shortly after the start of the Korean War. Recruits for this program were secured from top-grade mechanics who had had well-rounded experience in manufacturing. Graduates of technical

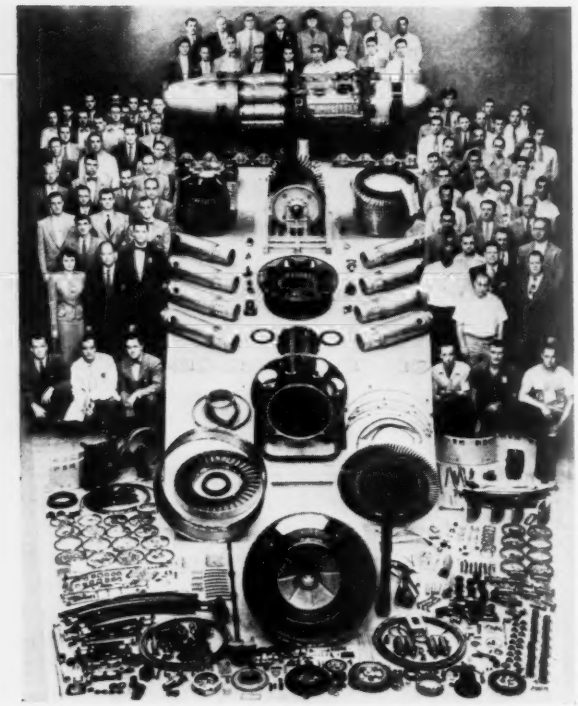


FIG. 4. It takes 87 kinds of specialists and 8,854 parts to build a jet engine.

schools such as the Academy of Aeronautics and the state technical institutions were also recruited as trainees. This course varied in length from 16 to 26 weeks, depending upon the background of the trainees. It included such information as blueprint reading, methods of material preparation, methods of forming

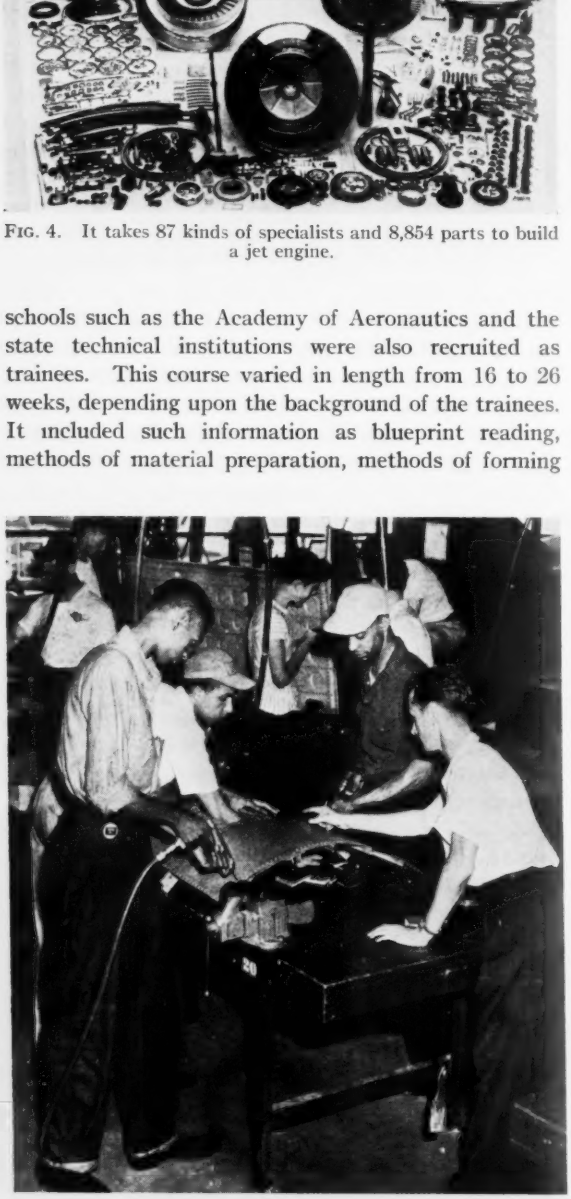


FIG. 5.

and the determination of the most feasible and economical means, machine limitations, and actual job sheet writing.

Another problem that presented itself during the last build-up of personnel was the training of tool and die makers, those artisans who build the tools with which the various parts of an aircraft are made and assembled. With every foot of space in the plant needed for production, it was decided to utilize existing training facilities in the area. To date, the shop facilities of the Long Island Agricultural & Technical Institute and two high schools have been used to train these important workers.

The course itself was developed by a group of supervisors from various sections of the tool shop. Many of these supervisors, after completing their day at the plant, went to the schools and helped in the instruction of trainees for 2 or 3 hours. It might be interesting to note that all of these men, after receiving some teaching instruction in the Training Department and under the guidance of the various directors of Adult Education in the schools, were all granted State Teachers licenses, making them more valuable employees to the company. Materials used for this program were mostly scrap from the plant.

Trainees selected for this course were required to have at least 3 years' mechanical experience. Many of them had been automobile mechanics. In addition to screening and interview, they were selected on their ability to pass two tests—one, a test of mechanical comprehension, and the other, a short test in mathematics.

This course was originally given on an 8-week basis. However, when higher grade tool makers were needed, the course was extended to 12 weeks. Upon the addition of optical tooling, it was extended another 3 weeks, to 15. A brief outline of this course is attached as an Appendix to this paper.

When the need for inspectors arose, a similar course was developed by Inspection Department supervision and was also given at the Long Island Agricultural & Technical Institute. This course was of 6 weeks or 240 hours' duration.

Despite the engineering brains that go into the design of our modern-day aircraft and the work of the technicians who devise the means of building and assembling the parts, one rivet improperly driven or a nut improperly torqued may ruin everything the engineers and technicians have wrought. How, then, are we to train the unskilled man power that is available to build and assemble our planes properly?

Probably the largest categories of workers in any airframe plant are those of riveters, assemblers, and bench mechanics (see Fig. 5). Early in 1951, when production was first increased, it was decided to establish a "vestibule" training school and to utilize the facilities and years of training experience of the Academy of Aeronautics.

At first, courses were conducted at the Academy's La Guardia Field, N.Y., location. In August of that

year, a branch facility, the Casey Jones School of Aeronautics, was opened in South Farmingdale, approximately $1\frac{1}{2}$ miles from the Republic plant. Courses consisted of 80 hours of instruction in 2 weeks. During the first year, a total of 3,047 employees were trained at these two locations.

The curriculum was developed at conferences held jointly between Republic factory management, its Training Department, and instructors from the Casey Jones School. To date this school has trained over 11,000 employees as riveters, assemblers, and bench mechanics, in addition to several hundred electricians and welders (see Figs. 6 and 7).

How were these courses developed? First, an analysis was made of the knowledge and skills required to do a specific job (see Fig. 8).

Before any program in skills training can be developed, we must first know what the workers are required to do. In this column we list the various operations the worker is required to perform. Second, what does he use to perform these various operations in the way of materials and tools? Under materials, the type of materials and their recognition and working properties are listed. As an example, we might use the difference between the various types of aluminum-sheet stock, or the difference between AD rivets and DD rivets. Under tools, we list the type of tools required for each operation, the care of these tools when used, and the care of these tools when not in use. As an example, how does an inspector handle a micrometer? Under its care and use, it is not used as a "C" clamp. From analysis it has been found that the safest place to carry it when it is not in use is in the inspector's watch pocket. He never puts it in his shirt pocket from which it might drop to the floor and be damaged.

Referring to the second part of Fig. 8, before any training program can be inaugurated, we must determine what related knowledge is required. In other words, What He Must Know. Under mathematics, is there any figuring? Under drawing, must he be able to read blueprints or do any sketching? What trade judgment must he be taught in order to perform his job? A machinist never uses a 14-in. Stillson wrench to tighten a $\frac{1}{4}$-in. bolt. Which bolts in an assembly should be torqued with a torque wrench, etc.? Under testing, are there any tests that the worker may perform to check on his own work? What safety precautions must be observed in performing this operation? Last, but not least, what are the trade terms that are used by people in the industry which would be unknown to the trainee? As an example, we speak of a plane's empennage, dihedral of a wing, or Mach Number almost every day. The neophyte is unable to understand these terms without definitions.

During the last expansion of the aircraft industry, of which we have all had intimate knowledge, have come many problems both mechanical and human. I do not mean to intimate that the problems associated with the training of engineers and mechanical personnel have all been conquered; they haven't, and I doubt if they ever will be. On the human side, I do believe, however, that our biggest problem has been the training of new management personnel. The most likely source from which to draw this personnel has been from the group of top-grade mechanics and technicians who know the job of building aircraft. Although they had been excellent workers when they worked with tools, machines, materials, on drafting boards, and behind desks, they were now, overnight, required to work with human beings. We all no doubt remember the late Friday afternoon appointments of new supervisors that we

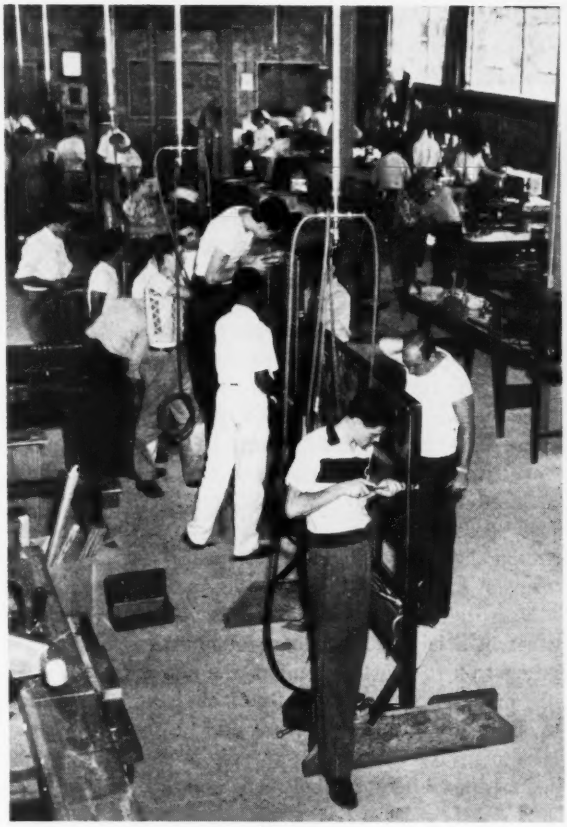


FIG. 6.

FIG. 7.

were required to change over a weekend from a mechanic or draftsman to a part of management by Monday morning. Some were able to bridge the gap with little difficulty, while others, given authority, acted like the proverbial old-time top sergeant or went to the other extreme and became a Caspar Milquetoast.

The attitude of a lot of our new workers can probably best be illustrated by a story about Sir Christopher Wren. It will be remembered that Sir Christopher was one of the outstanding architects in Great Britain. He designed St. Paul's Cathedral in London. One day after construction had been started on the Cathedral, he visited the site and saw two stone masons dressing stone. He turned to them and asked what they were doing. The first man replied that he was dressing stone—the second said that he was building a Cathedral. Of the thousands of new workers we have all hired and promoted, we still have too many who are just "dressing stone." In other words, they are still drilling holes or drawing lines instead of thinking in terms of completed planes for the Air Force and Navy.

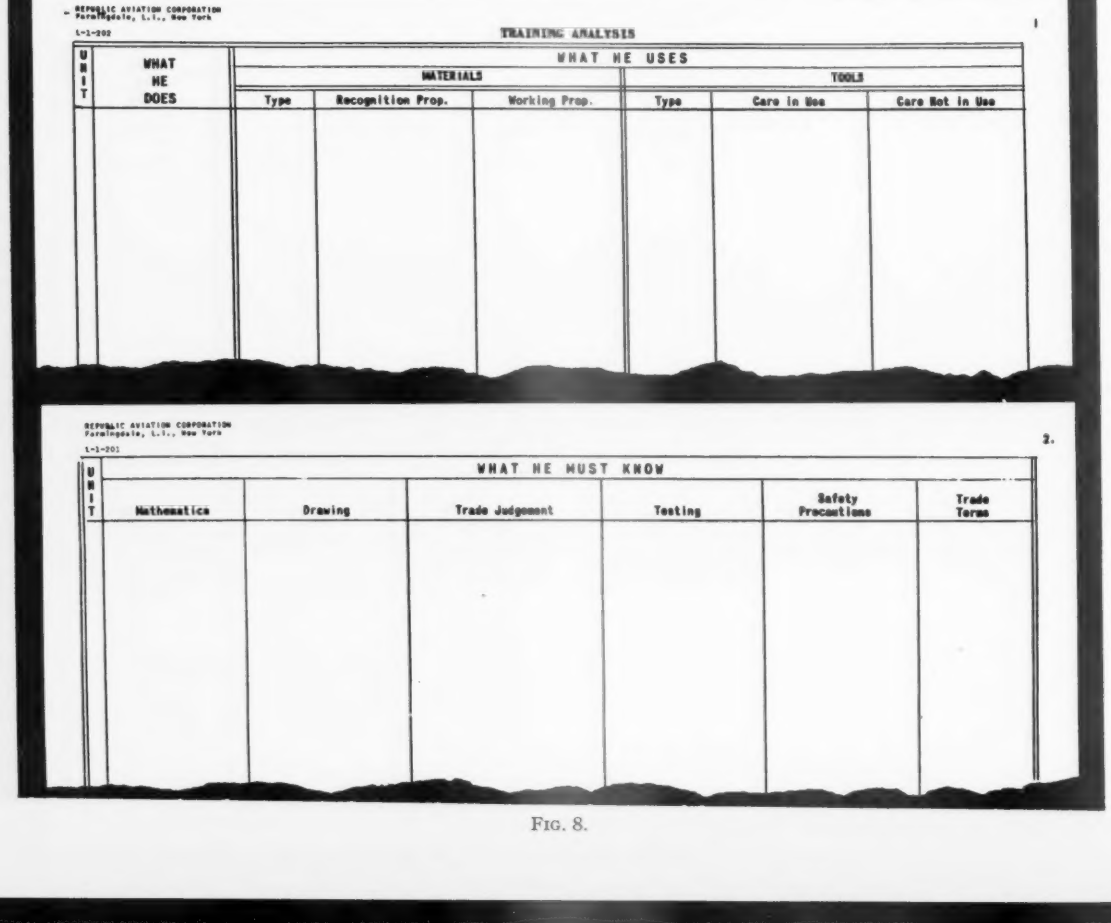
How did this lack of interest develop? Was it because of a lack of knowledge of human relations and interest on the part of some of the new supervisors we had made, or was it due to the fact that we had failed to train them before they were made supervisors? How many of these new supervisors could accurately define the difference between compliance and cooperation? How many of them were securing only compliance from their workers when they thought they were getting cooperation?

Many companies, after analyzing these problems, developed supervisory training conferences for both their old and new supervisors. At Republic Aviation Corporation, such conferences have been continued for the past 3 years on a weekly basis. Each supervisor from the rank of Assistant Foreman in production departments and from Group Leader in indirect labor departments have been required to attend a 1-hour conference each week. Approximately 60 per cent of the material covered in these conferences has dealt with the human relations aspect of the supervisor's job of dealing with people.

These conferences have also been used as a medium of communication up, down, and across organizational lines. They have also been used as a means of problem-solving. It is in this phase that training more than pays for itself.

During a single course of some 20 hours duration, in which the supervisors analyzed, examined, and considered our operational costs, they were able to identify and prevent many serious leaks that were unnecessary costs over which they exercised control. The purpose of this program was sixfold.

In analyzing our costs of operation, the supervisors were shown that the sales dollar or selling price of our


REPUBLIC AVIATION CORPORATION
Farmingdale, L.I., New York

1-1-202

TRAINING ANALYSIS

1

UNIT	WHAT HE DOES	WHAT HE USES					
		MATERIALS			TOOLS		
		Type	Recognition Prop.	Working Prop.	Type	Care in Use	Care Not in Use

REPUBLIC AVIATION CORPORATION
Farmingdale, L.I., New York

1-1-201

2.

UNIT	WHAT HE MUST KNOW					
	Mathematics	Drawing	Trade Judgement	Testing	Safety Precautions	Trade Terms

FIG. 8.

product must be sufficient to cover all the costs of that product—or our business might fail (see Fig. 9).

They were further shown that the habit of accepting certain types of costs as inevitable was a fallacy and that, if we were to produce competitively, we needed to obtain quality and quantity in the most economical manner. In other words, the main objective of our industry was to give to the Air Force and Navy the right amount of the right material at the right place at the right time and as economically as possible. Further, we sought to show that each member of our management team was and is in competition with the person at the same management level in the plants of our competitors and that it is only by accepting this theory that we will be able to produce greater quantities of quality products in less time by making the best use of available man power, machines, and material, thereby controlling costs.

In summary, what may be gained by adopting a formalized training program? Many managements are still inclined to choose on the basis of immediate costs, and normally the old familiar on-the-job training appears to be the more reasonable. The costs of this type of training are buried in overall production costs. Actually, it may be the most expensive. Consider the fact that, when an individual trainee is being trained on-the-job, he will require a large proportion of another worker's or supervisor's time. Compare this with "vestibule" training where a single instructor may train anywhere from 12 to 20 trainees at a single time.

Second, training on-the-job is normally conducted with the trainee working on regular production work. If mistakes are made and parts are ruined, think of the loss of labor and material that may have already gone into the work prior to the operation that the trainee was performing. Again, compare this with "vestibule" training where all work performed uses scrap materials and parts.

Third, a better job of selection may be accomplished when training is conducted on a "vestibule" basis. The General Electric Company learned this fact almost 20 years ago when it started training instrument workers. During the first week of training, each trainee practiced eight different jobs before it was decided which one he was best fitted for.

Believe me, training in itself is an investment and not an overhead item. If this is hard to believe, take only a moment and look at the Ford Foundation, the General Motors Institute and the training programs being continuously conducted on a "vestibule" basis by the Bell Telephone System throughout the country. Is the operation of a switchboard more difficult than the work of any of our technicians or even riveters? The very lives of untold thousands depend upon how skillfully *they* perform their work.

If we are to secure a sufficient number of skilled engineers, technicians, and workers during the *next* half century of powered flight, we must realize that we will have to make a large proportion of them ourselves—by training.

1. TO HELP EACH MEMBER OF OUR MANAGEMENT TEAM TO UNDERSTAND THE USEFULNESS OF THE SALES DOLLAR AND ITS LIMITATIONS.
2. TO HELP EACH MEMBER OF MANAGEMENT TO BECOME COST CONSCIOUS.
3. TO THINK IN TERMS OF MONEY EVERY TIME ANYTHING HAPPENS.
4. TO IDENTIFY THE MANY SERIOUS LEAKS WHICH ARE UNNECESSARY COSTS OVER WHICH SUPERVISORS CAN EXERCISE SOME CONTROL.
5. TO DETERMINE WHAT SHOULD BE DONE TO PLUG THESE LEAKS.
6. TO TAKE THE NECESSARY ACTION TO PLUG THE LEAKS.

FIG. 9. Cost program.

APPENDIX—OUTLINE OF TOOL AND DIE MAKERS COURSE

(I) Mathematics

(A.) Common Fractions.
(B.) Decimal Fractions.
(C.) Measurement.
(D.) Symbolism.
(E.) Equations.
(F.) Exponents.
(G.) Various Formulas.
(H.) Ratio and Proportion.
(I.) Geometrical Construction.
(J.) Right Triangle Trigonometry.

(II) Blueprint Reading

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(B.) Three-View Orthographic Projection.
(C.) Working Drawings.
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(E.) Limits and Tolerances.
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(G.) Surface Quality Symbols.
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Development Problems of the Large Helicopter

L. L. DOUGLAS*
Piasecki Helicopter Corporation

(I) Introduction

It is characteristic of the aircraft engineer to regard size as a problem of detail. Once basic principles have been established and proved, then the mission requirement is viewed for its fulfillment in the optimum arrangement.

The period of the helicopter concept, by DaVinci in 1500 A.D. to the autogyro flight across the English Channel in 1928 by Cierva, was used in developing rotary-wing flight principles. Between 1937 and 1939, Heinrich Focke proved the practicability of the helicopter by establishing records of endurance, speed, and altitude which fired the imagination of the world in the helicopter possibilities. In the relatively brief span of 15 years since, approximately 40 types of helicopters have been procured by the Military of this country alone, ranging in size from a gross weight of 700 to 35,000 lbs. and in powers up to approximately 4,000 hp. In reviewing this rapid progress, it is of interest to note that eight rotor configurations have been built and flown successfully. During this period, helicopter engineers settled down to the problems of achieving reasonable useful load to gross weight ratios combined with the ability to hover at altitude and fly at speeds beyond 100 m.p.h. Mechanical reliability, stability, comfortable vibration and noise levels, and all-weather operation were principal problems attacked with vigor. We have now entered a new era of the large helicopter—size dictated by requirements of multiengine reliability, load-carrying capabilities, and economic transportation.

In the development of the large helicopter, where cost of engineering and manufacture is so sizable, it is important that close coordination of design, of development testing, and of manufacturing quality control be maintained.

(II) The Design

The design of a large helicopter starts with its mission or principal purpose. Although the size itself is generally established merely by how much pay load and fuel are required for performing the mission, the optimum rotor configuration is established by the type of mission itself. For example, the requirements of air rescue and antisubmarine warfare are similar in that they both need large fuel loads with relatively low pay loads. However, they differ in that air rescue requires high speed, long range, and high altitude, whereas the antisubmarine characteristics call for low speed, high endurance, and low altitude. Further, a helicopter designed for troop transport needs a large cabin volume to handle troops, litters, and vehicles, as compared with the requirements of air rescue and antisubmarine warfare. The range and speed problems of a transport helicopter may be different depending on whether the usage is for assault or close-in ground support. Additional limiting items that affect the over-all design may be associated with whether the helicopter is intended for carrier operations and its attendant blade folding and deck-handling characteristics. Generally speaking, helicopter cabin requirements are not very different from those of the airplane for similar missions. In Fig. I, a side-view photograph of the XH-16 helicopter, the fuselage similarity to that of fixed-wing aircraft of its size is immediately apparent. However, the fact that the helicopter may additionally make use of an external sling to carry items of equipment which cannot be contained within the cabin or which is more convenient operationally to carry outside is an important consideration. Fig. II is a photograph of an

Fig. I. Side view of XH-16.

Fig. II. H-21 carrying Army shelter.

Presented at the Rotating Wing Aircraft Session, Twenty-Second Annual Meeting, IAS, New York, January 25–29, 1954.

* Vice-President in Charge of Engineering.

H-21 helicopter carrying a 2,500-lb. Army shelter from an external sling. Later sling design will support the cargo at or near the helicopter center of gravity. This will permit the handling of large items of cargo weight without adversely affecting the control of the aircraft due to the swinging cargo.

The question often arises in military aircraft, as it does in commercial, as to the economics of size for troop and cargo operations where a large volume of low-density cargo is to be transported. Is it more economical to perform this operation with many moderate size helicopters or with fewer larger helicopters? Fig. III is a plot of a cost of operation of cargo helicopters varying in weight from approximately 6,000 to 50,000 lbs. It is thus apparent that, other than the ability to carry single items of large load, the large helicopter is more economical to operate as a transport and cargo vehicle.

It is usually desirable to map the rotor configuration for the mission requirement in order to arrive quickly at the approximate rotor parameters in order to narrow down the area of investigation. A performance map such as shown in Fig. IV is helpful in reducing the scope of the problem. It is apparent that for a high ratio of gross load to power, the low disc loading, low tip speed helicopter is optimum. This is accomplished at the expense of forward speed. To attain relatively high speeds, high tip speeds are required with the consequent reduction in gross load power ratio. In that regard, Fig. V is of additional interest. It points out that, whereas the piston engine is most efficient in the low disc loading, low tip speed régime, the turbine will operate efficiently at higher tip speeds and disc loadings.

Both on the ground and in the air, the helicopter, made up of rotors, drive system, fuselage, and alighting gear, is a single dynamic unit and must be treated as such. On the ground, the oscillation of the blades around the lag hinges couples with the oscillation of the fuselage on its oleos in what is commonly called ground resonance. Hence the importance of lag hinge dampers on the rotor blades and adequate damping in the oleos. Fig. VI is a typical solution to a ground reso-

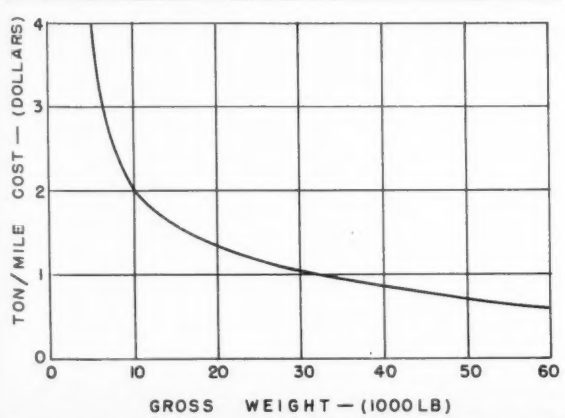

FIG. III. Operating costs of cargo helicopters (50 nautical mile radius).

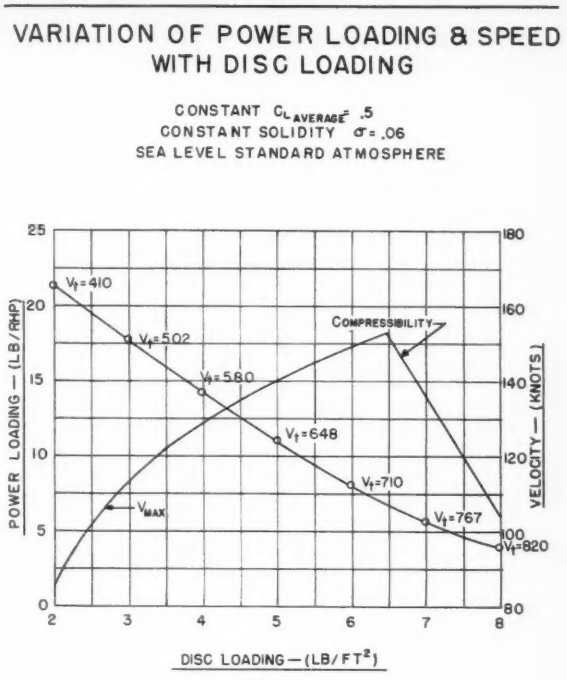

FIG. IV.

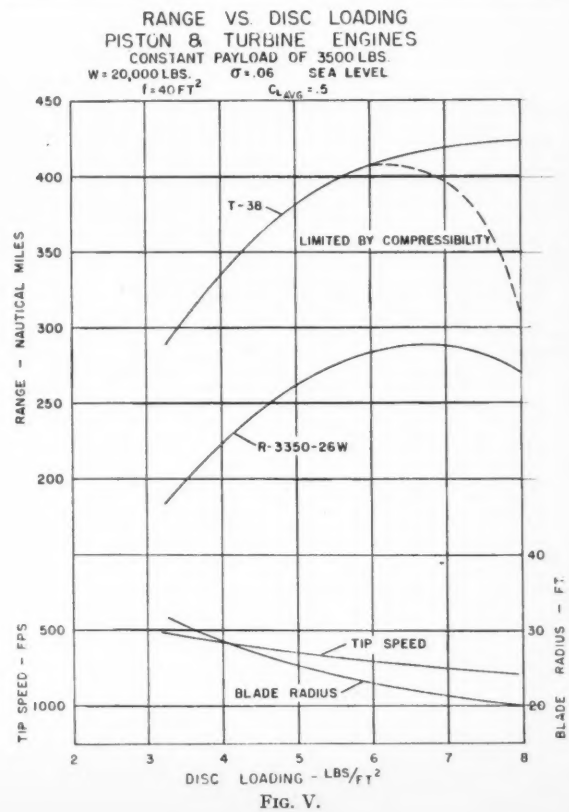

FIG. V.

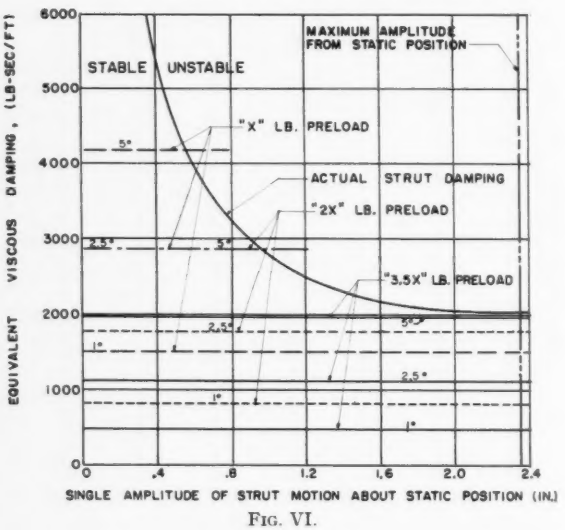

FIG. VI.

nance problem, where the required amount of oleo and blade damping is established in order to avoid ground resonance. Recently, important contributions to freedom from ground resonance have been accomplished in the development of controlled leakage blade dampers and oleos with flapper valves as a replacement for conventional metering pins. In both cases, the principle has been to obtain a relatively high amount of initial damping.

In the air, the rotating blades mounted on a fuselage develop cyclic forces to which the fuselage can respond and amplify if not properly designed. Thus, the design of the helicopter fuselage and the mounting for the rotor system is more than a mere structural problem, in that it involves a knowledge of the dynamics of such a system in order to minimize uncomfortable or destructive vibration. Fig. VII is a schematic of a fuselage and two rotors and the several modal shapes encountered in such an arrangement.

It is not sufficient to consider the helicopter only as a dynamic system on the ground and in the air. The power system itself, including the drive, must be examined for its contribution to the dynamics of the helicopter. This problem starts with the engine. As an important inertia member of the helicopter dynamic system, the power plant is in an environment very different from that of the fixed-wing aircraft for which it was developed. As a result, an aircraft engine inevitably goes through some modification program during its service life in a helicopter. Many helicopter manufacturers find it convenient to install the engine in some inclined attitude from 10 to 70 deg. from the horizontal. Inevitably, this has an adverse effect on valve lubrication and rockerbox scavenging which must be corrected. Decoupled from a rotor system, with a relatively small flywheel as compared with the large inertia propeller it powers on airplanes, the engine must be made to start easily, idle smoothly, and bring

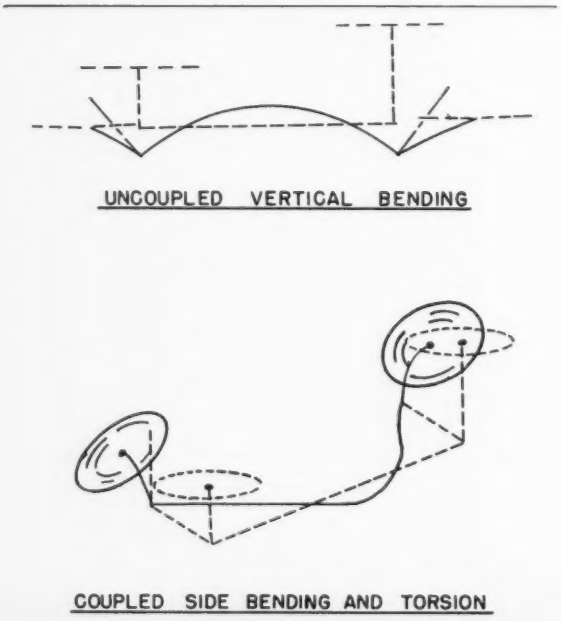

FIG. VII. Fuselage mode shapes.

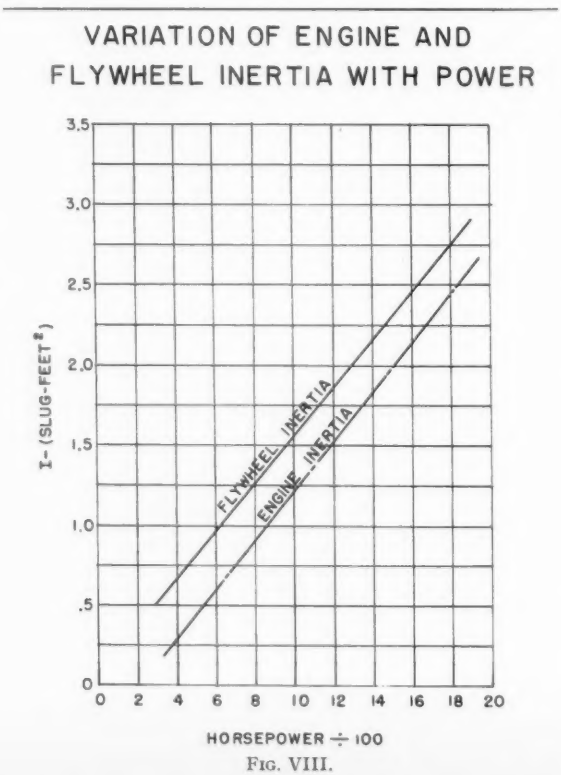

FIG. VIII.

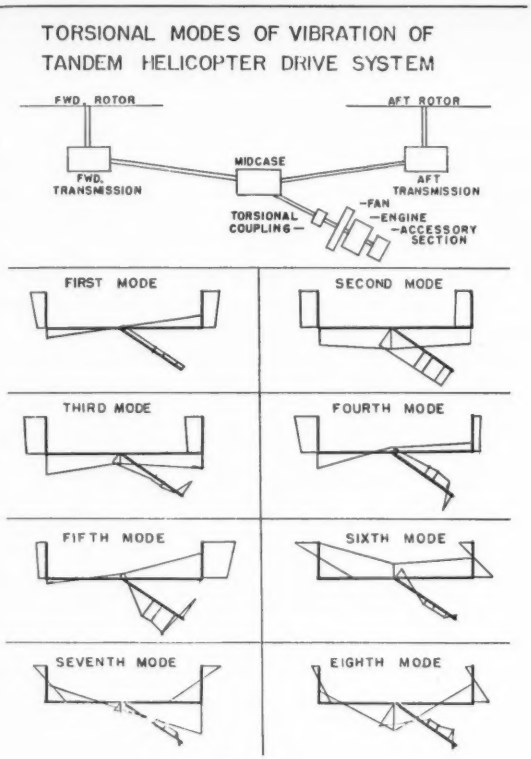

FIG. IX.

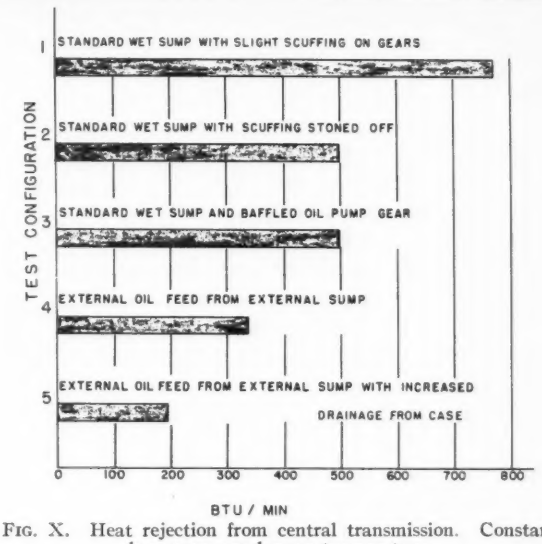
TEST CONFIGURATION
1 STANDARD WET SUMP WITH SLIGHT SCUFFING ON GEARS
2 STANDARD WET SUMP WITH SCUFFING STONED OFF
3 STANDARD WET SUMP AND BAFFLED OIL PUMP GEAR
4 EXTERNAL OIL FEED FROM EXTERNAL SUMP
5 EXTERNAL OIL FEED FROM EXTERNAL SUMP WITH INCREASED DRAINAGE FROM CASE
0 100 200 300 400 500 600 700 800
BTU / MIN

FIG. X. Heat rejection from central transmission. Constant horsepower and sump temperature.

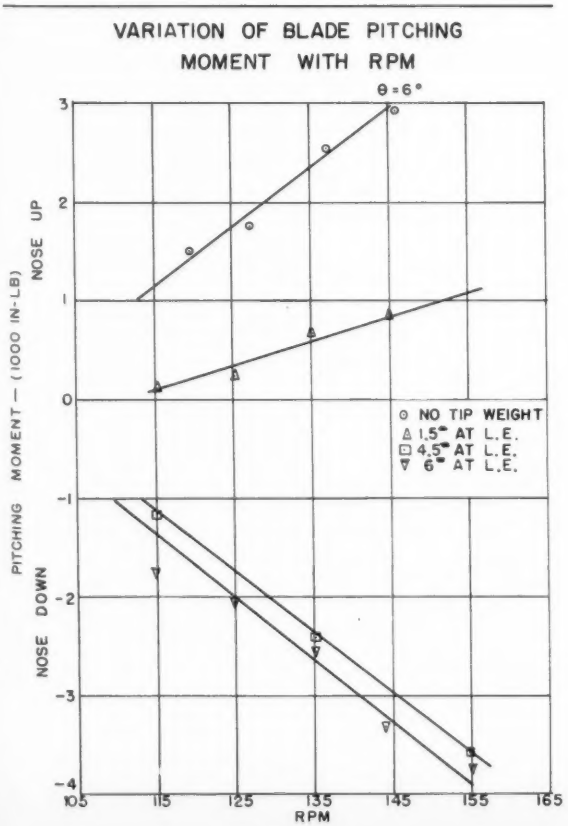

FIG. XI.

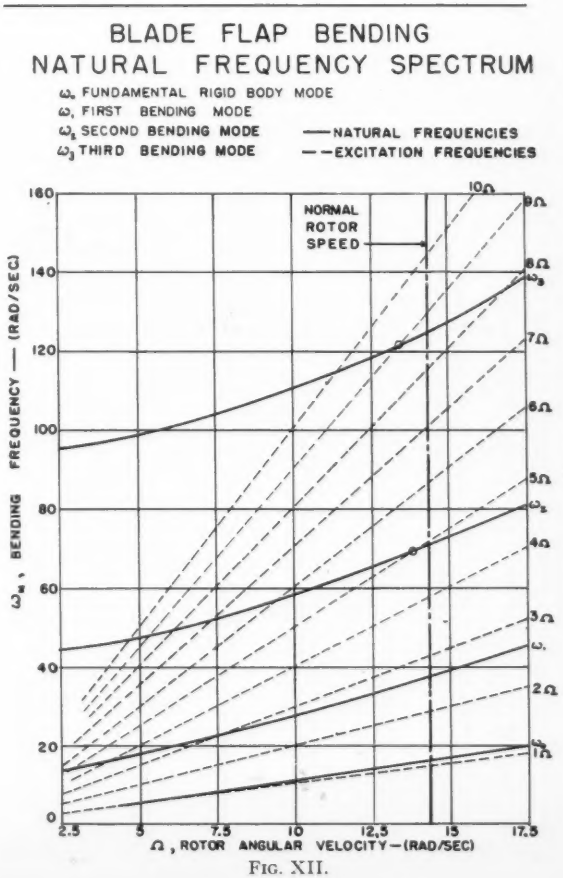

FIG. XII.

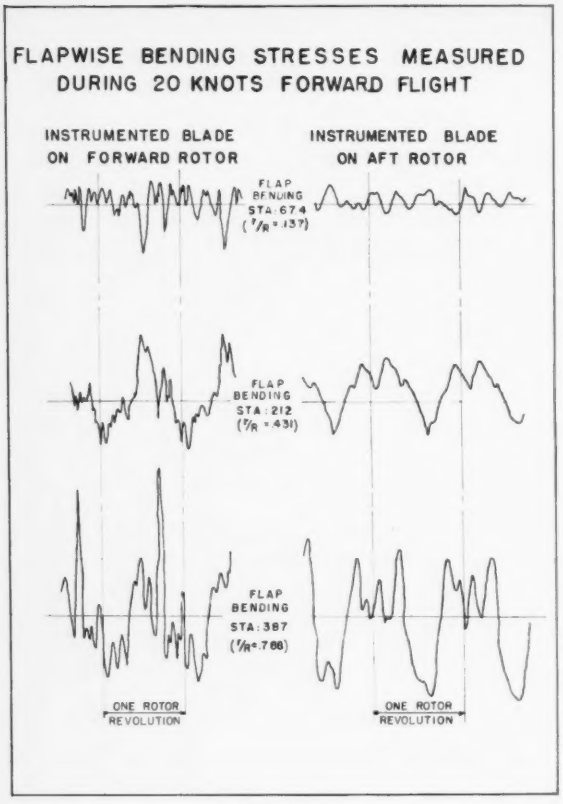

FIG. XIII.

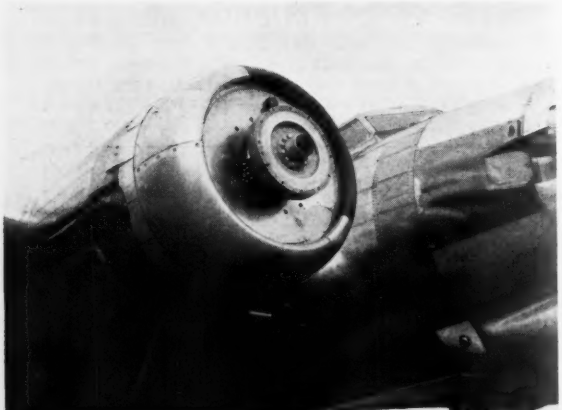

FIG. XIV. Wright R1820-103 engine installation in B-17.

FIG. XV. H-21 rotor test stand.

the rotors up to speed in approximately 20 sec. in all weather conditions from −65° to 100°F. Throttle forces and friction, which normally are not a problem in the fixed-wing aircraft, must be low enough in the helicopter for the pilot to easily operate a conventional throttle twist grip. Since inadequate flywheel usually results in poor starting, unstable idling, and premature failures of the accessory drive system, it is of interest to examine flywheel inertias currently in use. Fig. VIII is such a plot and shows the variation of flywheel inertias with power. Conventional piston engines have three important inertia items consisting of the flywheel, the engine inertia, and the accessory section. These three become an integral part of the helicopter inertia systems and must be considered as such. For purpose of analysis, the helicopter dynamic system may be considered schematically as shown in Fig. IX. It is seen that a relatively large number of modes should be examined in order to establish the structural integrity of the drive system.

The design of the helicopter drive for large helicopters is characterized more by a requirement of large gear reductions due to the low r.p.m. of the large rotors than by any unique principles of gearing. Since the drive system weight is a substantial item of the empty weight of the helicopter, it must necessarily be engineered carefully. Where the units are large, deflections of individual gear shafts and bearing supports need be analyzed. In addition, improper meshing of the teeth with regard to scuffing, pitting, and excessive sliding is immediately reflected in heat rejection. For the large powers transmitted by such gearing, small variations in power losses result in large percentage change in heat rejection and aggravate the cooling problem of the transmissions. Fig. X is an example of heat rejection variation in a single gearbox based on various design changes.

A rotor blade that has stable control loads, and dynamic characteristics that have minimum excitation in the operating régime, is essential to good helicopter flight characteristics. Since the stability and controllability of the aircraft is largely dependent upon the rotor blade behavior, careful design and a knowledge of the dynamics of blade operation is important. Fig. XI, for example, shows the effect of dynamic overbalance on the control loads and stability of an 82-ft. diameter rotor blade. It should be noted how even a small amount of overbalance has a large stabilizing effect on pitching movement characteristics. Fig. XII is a typical natural frequency spectrum of a large rotor blade. In this case, second mode of flapping, fifth harmonic, is closest to the operating régime and should appear in flight records. For comparison, Fig. XIII shows strain gage traces of this blade at three stations during flight at a transition speed of 20 knots. Predominant fifth harmonic stresses are apparent. Although it appears that rotor blade natural frequencies may be predicted by calculation with reasonable accuracy, the high cost of large blades may warrant the use of dynamic models as a check. This has been dem-

onstrated for a large-diameter jet-driven rotor, in that it was possible to simulate not only the behavior of the rotor blade itself but the pylon motion due to rotor-induced loads as well.

It is thus axiomatic that careful attention to design of all the components of the helicopter is essential in achieving an optimum relationship of these components to the helicopter as a whole. Since each has an important effect on the dynamics of the aircraft, the compatibility of the components to the system must be established.

(III) Testing

In any dynamic system, the adequacy of the design is established by its behavior with time. It is thus desirable that each of these units are life or endurance tested in an environment as closely simulating the actual installation as is practical. To the helicopter designer, this test phase is as important as the design phase. Since the state of the art is such that life and endurance does not lend itself to an exact mathematical prediction, it is important that any weaknesses or marginal characteristics be determined early in the design stage. The testing of large helicopter components presents some new problems associated with large size, large torques, or large powers. It should, therefore, be of interest to examine typical test installations of this type.

In an effort to ascertain as early as possible the behavior of the Wright 1820 engine at altitude, an H-21 power-plant installation was mounted in a B-17 for test purposes, using a flywheel instead of a propeller. Fig. XIV is a photograph of such an installation and was useful in checking magnetos and carburetors for starting and idling, both at sea level and at altitude. This test was followed by power-plant and transmission testing in a rotor test stand, as shown in Fig. XV. This stand is equipped with an H-21 power-plant installation, a sawed-off propeller, and a set of rotor blades. In this manner, it was possible to develop full power out of the engine to the propeller alone, or through combination of propeller and rotor. Development testing of the H-21 helicopter on the rotor test stand was followed by qualification testing on a full-scale

Fig. XVI. H-21 tiedown tests.

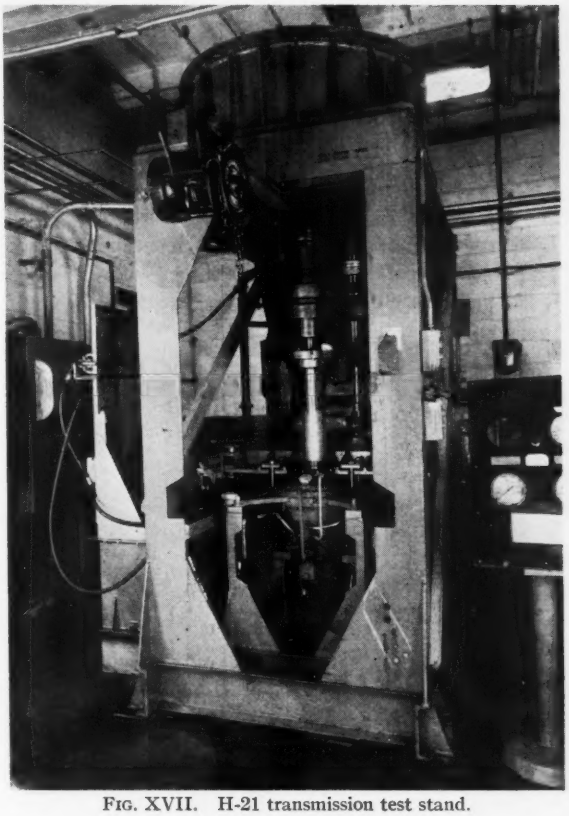

Fig. XVII. H-21 transmission test stand.

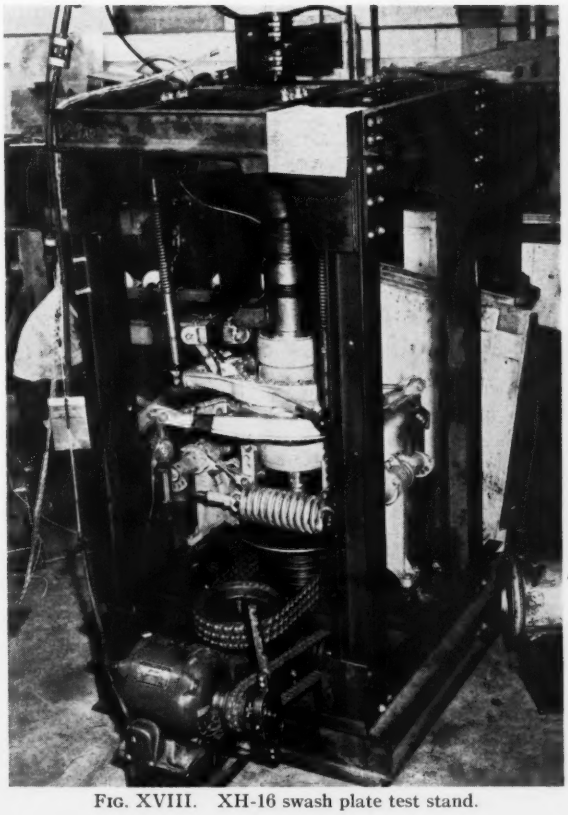

Fig. XVIII. XH-16 swash plate test stand.

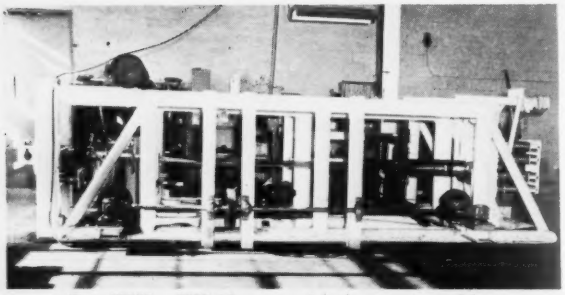

FIG. XIX. XH-16 root end fatigue test machine.

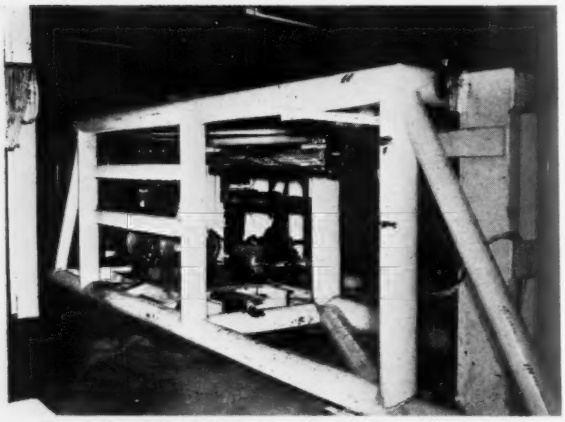

FIG. XX. XH-16 blade increment fatigue test machine.

FIG. XXI. WADC whirl tower.

FIG. XXII. XH-16 ground resonance test.

helicopter, as shown in Fig. XVI. Both the rotor test stand and the tiedown helicopter are means of testing components of the helicopter dynamic system *together* in order to ascertain their compatibility in an idealized vehicle, simulating the actual helicopter.

Prior to this stage, however, testing of the individual components *alone* to determine their ability to withstand the loads for which they were designed is desirable. Fig. XVII is a photograph of the back-to-back test stand for the load running of the H-21 transmissions. In this arrangement, an auxiliary gearbox of commercial design is looped into a circuit utilizing the H-21 gearbox and powered by an electric motor. Loads to the gearbox are applied by winding up the shaft in the closed loop. In this stand, the wind-up of the shafts is accomplished by a differential gearing system operated by another electric motor of large gear ratio. It is thus possible, by means of a small electric motor, to apply full horsepower to the transmission. On this unit, gearing and lubrication problems may be tested at an early stage in the development of the transmission and prior to its installation on the tiedown helicopter.

The entire upper control system, including the swash plate and pitch links can be tested in an arrangement such as shown in Fig. XVIII. Each of the pitch links incorporates a compression spring. The upper end of the pitch link-spring arrangement rides on a cam so designed as to develop, through the axial motion of the pitch link, the mean and cyclic loads on the swash plate. Not only the structural adequacy of the control components but the bearings and their attendant lubrication problems are thus investigated.

An interesting arrangement for applying centrifugal force, flapwise loads, and chordwise loads to the rotor blade and its attachment to the hub is shown in Fig. XIX. The blade is loaded axially by means of a gang of springs at the outboard end. A system of two bellcranks imposes cyclic moments in the chordwise direction at the inboard end of the blade and in the flapwise direction at the outboard end and at a frequency approaching the natural frequency of the system. By means of strain gages at convenient points, critical stresses in the inboard hinge and blade are measured. A typical outboard section of the blade is independently tested, as shown in Fig. XX. Here, the blade section is vibrated at its natural frequency with the amplitude of the vibrating unit so adjusted as to give desired stress on the blade section. By vibrating the section at its natural frequency, a relatively low-powered vibrating unit may be utilized to develop relatively high stresses in the large blade sections. After having proved the structural adequacy of the pieces, the blade itself is whirled on a whirl tower operated by the Air Forces at Wright Field, as shown in Fig. XXI. Here, the blades, hub, and hinge are completely instrumented, and r.p.m. and pitch are adjusted for a series of tests throughout the operating régime. Since there is no limit to the speed capacity of the whirl tower, over-

speed tests are possible on this tower which are not practical on a rotor test stand. When all the dynamic components have satisfactorily completed their bench and tiedown tests, the helicopter is ready for its first rev-up. This, too, is a critical stage in the preflight test program of a helicopter, for destructive ground resonance can occur. As a safeguard, a system of slack cables tied to the rotor head and snubbed by steel posts set in concrete is employed. Should destructive ground resonance take place, the oscillations may be brought under control by pulling on the cables before serious damage is done. Such an arrangement, used for the XH-16 helicopter, is shown on Fig. XXII. In this case, because of the size of the helicopter, a donkey engine with a hydraulic clutch capable of applying 30,000 lbs. was used. As an additional safety precaution, provision was made for a crew of 50 men to stand by at the cables to initiate a stabilizing load.

(IV) Quality Control

It is generally recognized that design and quality control are dependent on each other. On one hand, the control of quality depends to a large extent on the type of design. On the other hand, efficient design in terms of high stresses depends on the ability of the organization to maintain a standard of quality commensurate with that design. The control of quality involves different concepts depending on whether one thinks of it as inspection to drawing tolerances or the utilization of the properties of materials to their fullest potential. The engineer should know to what extent it is economically practical to obtain material relatively free of impurities and defects and to fabricate parts to finishes, tolerances, and hardness that will produce lightweight components consistently and economically.

A simple example of this problem is the installation of an ordinary ball bearing. The bearing rating has been established on the basis of an installation to certain fits of the bearing in the housing and on the shaft. Should these tolerances be exceeded, the bearing may be preloaded with resultant reduction in life, or so loose as to creep on the shaft or in the housing, thereby damaging the installation. Since these tolerances are relatively close, it is mandatory that the engineer design the parts such that tolerances and finishes of this type are readily obtained without special and com-

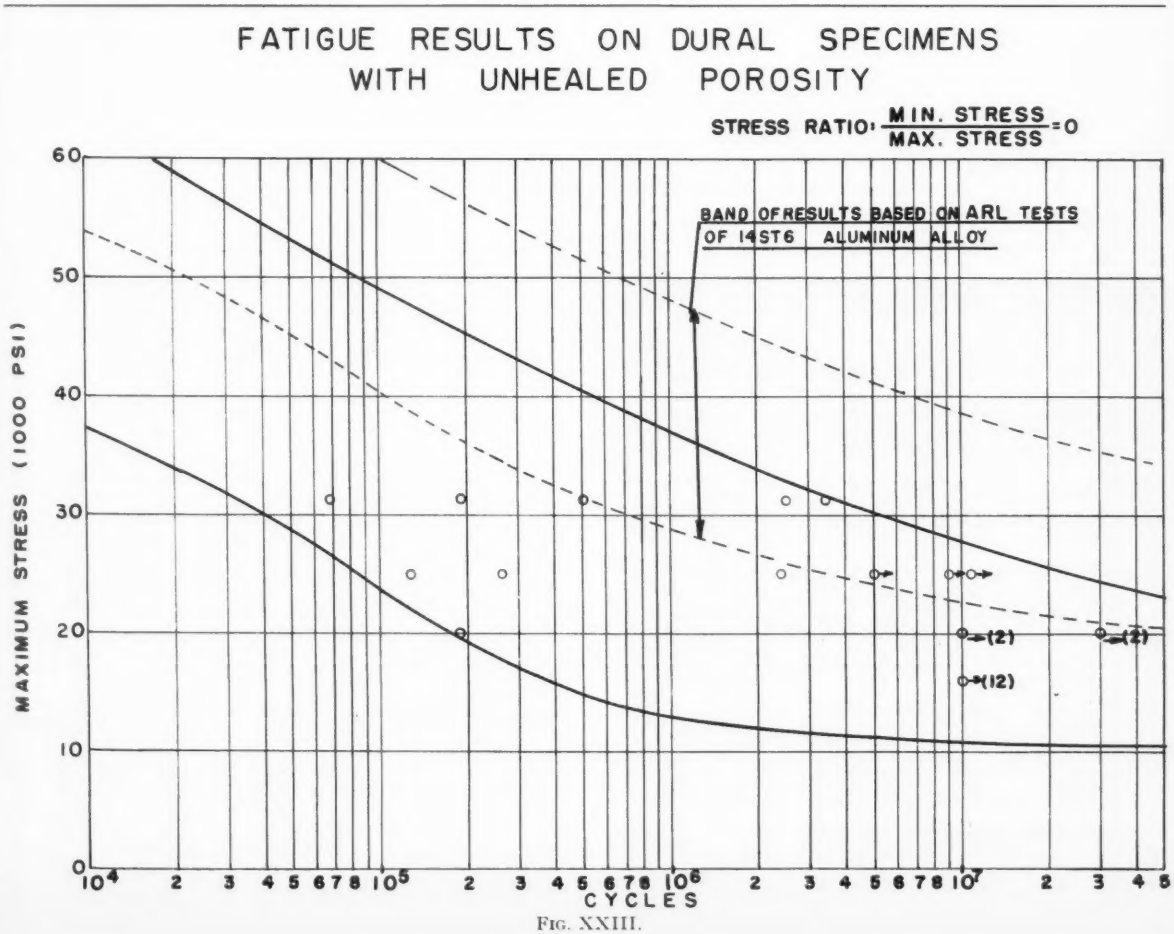
FATIGUE RESULTS ON DURAL SPECIMENS
WITH UNHEALED POROSITY
STRESS RATIO = MIN. STRESS / MAX. STRESS = 0
BAND OF RESULTS BASED ON ARL TESTS
OF 14ST6 ALUMINUM ALLOY
MAXIMUM STRESS (1000 PSI)
60
50
40
30
20
10
0
(2)
(2)
(12)
10⁴ 2 3 4 5 6 7 8 10⁵ 2 3 4 5 6 7 8 10⁶ 2 3 4 5 6 7 8 10⁷ 2 3 4 5
CYCLES

Fig. XXIII.

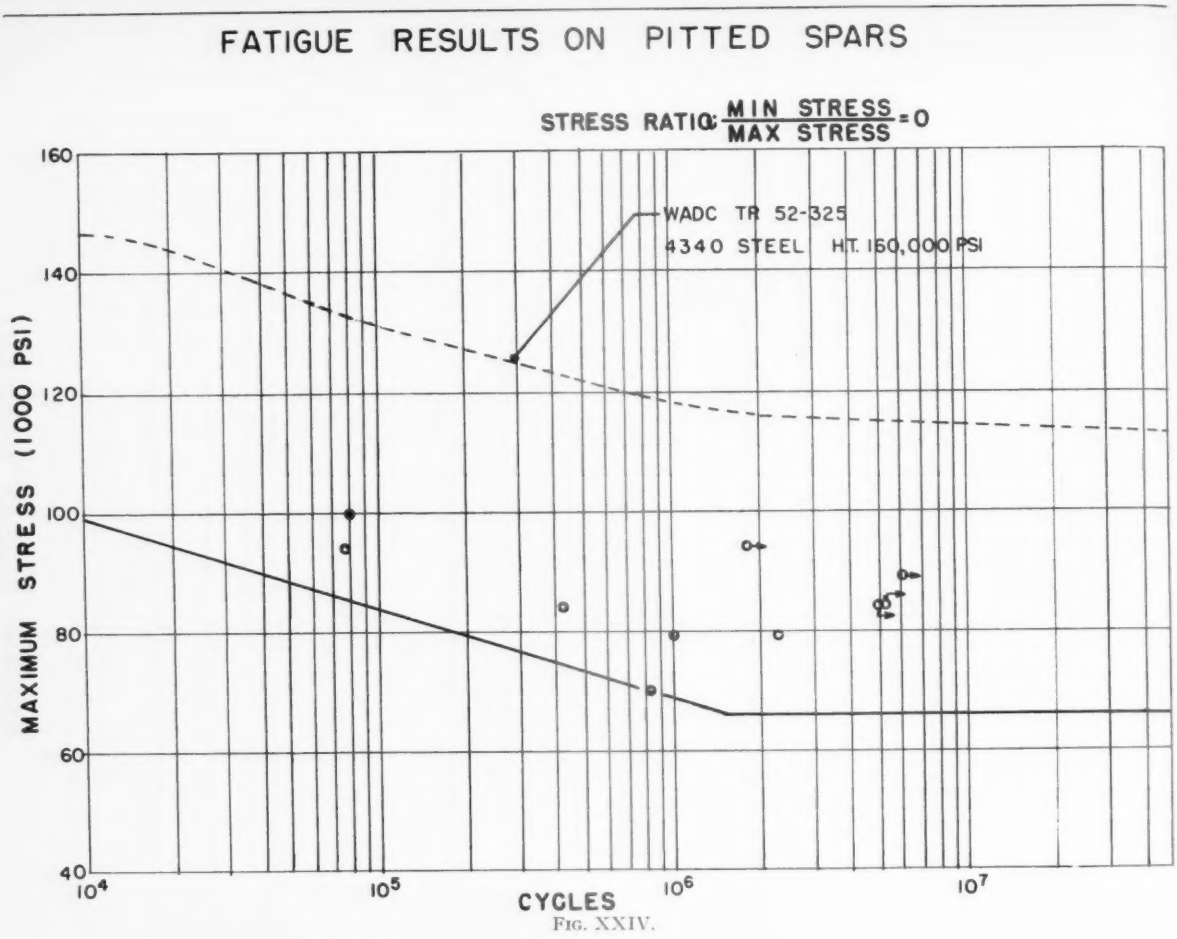

FIG. XXIV.

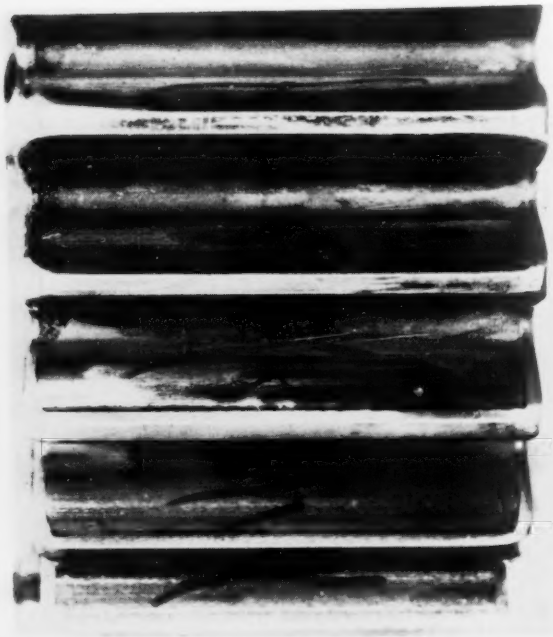

FIG. XXV. Gear cracks due to residual stresses.

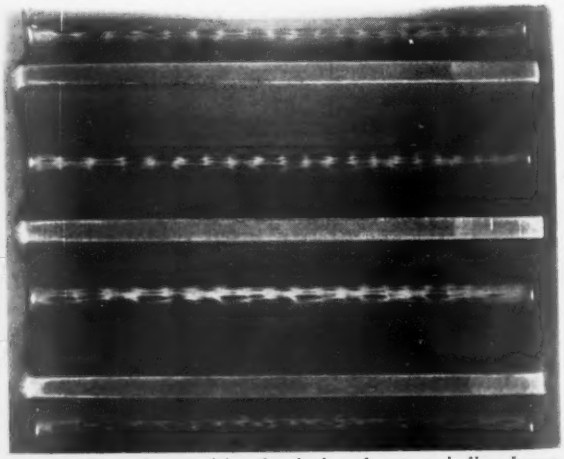

FIG. XXVI. Gears with rehardening due to grinding burns.

plicated machine setups. In a larger helicopter, this problem becomes increasingly difficult to attain. Therefore, it is necessary that the design reflect this problem in minimizing the requirements for the same tolerances as was easily possible in smaller components.

The problem of quality control with size is reflected in almost every component of the helicopter. In Dural billets, and forgings, the problem of unhealed porosity is one that is relatively unknown in the smaller sizes. Fig. XXIII is a plot of fatigue tests of tension coupons cut out of billets that contain unhealed porosity. In steel, freedom from dendritic structure, banding, and nonmetallic inclusions are problems that cannot be eliminated completely but must be considered in the design. A recent experience was one involving the pickling of large tubes for cleaning. The difficulty of handling was such that overpickling resulted with a consequent pitting of the steel tubes. Fig. XXIV shows the reduction of the fatigue strength of pitted spars as compared with standard material. This same figure also shows the effect of vapor and sandblasting as a salvage measure to offset the damaging effects of overpickling.

Especially sensitive to process quality is the manufacture of large gears. In order to develop high capacity, accurately ground carburized gears are generally used. This involves many machining, stress-relieving, carburizing and heat-treat processes—all of which can introduce residual stresses for which there is no nondestructive method of inspection. Fig. XXV is a photograph of cracks in gears attributed to residual stresses from improper processing. These cracks occurred in some cases in less than 1 hour of load running on a test stand. This condition was entirely corrected by process changes. Fig. XXVI is a photograph of severe grinding burns in a form grinding operation. This condition rarely occurred in small gears; in the larger sizes special attention to cooling, size of cut, and wheel grit size was required.

(V) Summary

The few experiences here mentioned are typical of the many associated with the development of large helicopters. It is not the intent of these comments to overemphasize the problems associated with the manufacture of large helicopters but merely to point out that there are additional problems resulting from size. Like any other development, once the problems are exposed they are generally susceptible to ready solutions.

Personnel Training Required to Produce Large Quantities of High-Performance Aircraft

(*Continued from page 59*)

(G.) Use and Function of Measuring Gages and Indicators.
(H.) Use of Transits and Optical Positioners.
(I.) Fastening Devices.

(IV) Shop Work

Shop work included the actual building of many jigs and fixtures, starting with simple templates and working up through form blocks to actual assembly and installation fixtures. All tools and fixtures built were required to pass tool inspection using the same standards as used in the tool shop.

(V) Time Schedule

Weeks	Hours Per Day—Related work	Hours Per Day—Shop work
1–2	6	2
3–4	4	4
5–6	2	6
7–15	1	7

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(See page 122 of this issue.)

Airplane Design in Relation to Safety

R. W. RUMMEL*
Trans World Airlines, Inc.

Ninety-one thousand LAC fabricated parts; 11,000 vendor parts; 143,000 ft. (27 miles) of electrical wiring (7,224 individual wires). Integral wing panels replacing 1,500 parts and 5,000 rivets.

THE SUBJECT "Airplane Design in Relation to Safety" is as extensive as airplane design itself, as complicated as our newer transports, and as fundamental as mathematics. It applies to every aspect of airplane design, major and minor alike, for almost every airplane component, including such small items as rivets and wire terminals or such major items as landing gear or wing spars, can be, and sometimes have been, involved directly in matters of safety. Aircraft are made of an imposing number of detail parts that must be given proper and adequate design attention in order not to cause difficulty. Fortunately, however, the state of the art is now such that a very small percentage of the total number of parts or components actually do.

The remarkably good scheduled air-line safety record that has been attained can, I feel sure, be viewed as a tribute to the designers, to the operators who must exert constant vigilance, and to the federal authorities who establish minimum acceptable criteria and review and approve the aircraft for use in, in the case of the scheduled air lines, interstate commerce.

Safety is an ever-present consideration of responsible people involved in the manufacturing, operating, and legislative phases of the air transportation business. Safety is seldom absolute in any form of locomotion and in ordinary use is a relative term of reference. This single, all-embracing aspect of airplane design can cause more heated controversies, finger pointing, or "witch doctoring" than any other single aspect of design that I know of. And it is correct that it should—it is of vital concern to all of us, and the welfare of the industry is vitally associated with its attainment.

Volumes can be written and rewritten on the detailed aspects or considerations of safety with relation to airplane design. It is, therefore, necessary for me to take some liberties with, or, if you like, apply limitations to, this subject.

I thought it might be interesting to discuss an operator's views on some principles of design which, when diligently followed, will produce aircraft still safer and views on the desirability for certain improved designs and also to give you a few examples of why these things

Presented at the Flight Safety Session, Twenty-Second Annual Meeting, IAS, New York, January 25–29, 1954.

* Chief Engineer.

are true. Even with the subject so limited, all aspects can hardly be covered in this paper.

The first principle I wish to discuss is this: Design aircraft so the least likelihood for transmitting inaccurate or misleading information to the flight crew exists. Incorrect information can create unnecessary conditions by causing the pilot to take what in an emergency would be correct action but which in reality would be inappropriate under the circumstances. Perhaps the most vicious items falling in this category are the false warnings, especially the false fire warnings.

Virtually every fire-warning system with which we have had experience has been subject to a certain number of false warnings in service. These have been too frequent and indicate the need for improvement in reliability. Such systems should provide positive emergency indication, give no false warnings, and should be capable of easy manual but preferably automatic continuity checks. Some of the newer systems give some promise of improvement in certain directions but more needs to be done. Perhaps the necessity for the development of more reliable turbine engine temperature indicators will pave the way for better detection systems.

To cite an example of how misleading incorrect information can be, a case was reported sometime ago wherein the warning light for a cabin heater compartment came on in a modern four-engined pressurized aircraft cruising at about 18,000 ft. The pilot went through seemingly appropriate procedures, including discharging the fire-extinguishing agent, after which time the warning light went off. A few minutes later the same warning light came on and the pilot again discharged CO_2, whereupon the light again went out. A short time later the warning light came on a third time at which time the pilot put the airplane into an emergency descent, landing at the nearest field under far from ideal conditions. The descent and landing were executed safely. Upon examination of the heater compartment it was found that no fire had existed but that an intermittent short occasioned by fatigue was the cause of all of the warnings.

I can cite another case in which a false warning led the pilot to land his four-engined, advanced-type transport in unfamiliar locale on a paved strip only 2,500 ft. long without reverse thrust. While the landing was made safely without damage to the aircraft or passengers, it was not under the best of conditions, to say the least, and except for false warnings would never have been attempted.

Many air lines have experienced a certain number of such incidents. A number of false warnings could be avoided by closer attention to detail design, including more adequate support for, and improved abrasion resistance of, wires, better terminal design by making installations less vulnerable to fatigue and less vulnerable to damage from necessary personnel handling, and such obvious things as thermocouple location and temperature range. To illustrate the last item, a series of aborted take-offs on a certain type airplane were necessary because the warning unit was located so that, with the cowl flaps in position for take-off, on hot days the detection unit became too hot and responded with an indication. This condition has been corrected, but it certainly never should have existed. Another new type airplane reportedly had identical difficulty even though it was manufactured a full year later. It, too, has been corrected. In each of these cases such testing of the systems as was done by the designer obviously did not simulate actual operating conditions or consider the necessary operational tolerances.

While none of the cases of false warning referred to here resulted in accidents, an exposure to potential trouble was involved which, if repeated often enough, would be caught up with some day by the law of probability.

Other types of misinformation that can lead to trouble are false landing gear position indication, incorrect flap position information, and incorrect fuel gages, not to mention incorrect flag position on flight indicators, incorrect instrumentation, incorrect navigation information, etc.

I presume it is hardly necessary to mention that repeated false indications can be vicious, since repetition is disarming and tends to breed neglect and/or lack of confidence in the warning system involved. This applies to both false *danger* as well as false *safety* warnings.

The second principle of design is always to provide simple means whereby the pilot can expeditiously, intelligently, and reliably cope with such emergency situations as may arise. To illustrate this I point out that one recent aircraft has a single switch that deactivates all of the nonessential electrical loads and other loads not required to maintain straight and level flight retaining minimum navigation and communications equipment. Thus, when the pilot receives a warning indication or suspects electrical system difficulty, he must do one thing and one thing only—throw an emergency switch that deactivates a bus powering approximately 90 per cent or the electrical system. The chances are then about ten to one that he has also deactivated the source of trouble. Then it is probable he can hunt for the trouble by activating suspected circuits one at a time on a less urgent basis. The same type of thinking and planning can and should be applied to a reasonable extent to other aircraft systems in future aircraft.

We have long believed that emergency systems, such as fire extinguishing, flare release, firewall fluid shut-off valves, and the like, should be manually actuated rather than have their usefulness dependent upon the integrity of a power system. This, quite obviously, is because the system that caused the emergency to arise may be the same system that powers the emergency device, thus making advisable protective action impossible. However, as aircraft become larger, the practicability of manual systems diminishes, which is by way of saying, and I hope I am not being reactionary, that because of the size problem all the more justification exists for the application of design ingenuity to match the reliability of the simple direct manual system. To

further emphasize this general point, it should be kept in mind that major accidents are seldom caused by the occurrence of only one unusual circumstance but are almost always the result of a combination of several unusual circumstances, all usually compounding against safety at a critical time.

Quite obviously, the simpler an aircraft can be made, the greater command the pilot will have of such emergency situations as may arise. An aircraft of really simple design should present a relatively simple emergency evaluation problem for the crew and, in addition, should have the advantage of being an airplane that is relatively easy to operate and, perhaps most important of all, one that is the least subject to mechanical failure. However, an airplane designed specifically to simplify cockpit procedures for normal operation, itself an important safety attribute, is not necessarily an airplane that can be readily diagnosed under emergency conditions. For example, one way to simplify cockpit procedures is to make systems more and more automatic so that the flight crew is able to devote more time to matters other than detail. Pressurization, air flow, and temperature controls in some late type aircraft are examples. Autoelectric load monitoring, automatic fuel tank selectors, and inertia switches are a few examples of devices aimed at relieving the flight crew of detailed duties that can detract from what is normally the main job at hand. The addition of automatic systems and gadgets adds considerable complexity to the airplane which, while on one hand improves safety by relieving crew work load, on the other hand can very noticeably complicate the crew's problem of coping with emergency situations because this very added complexity of design adds to the difficulty of making rapid analysis of the cause of trouble, as well as determination of the proper corrective action. Also, the greater the number of accessories and, the more extensive and complicated the systems, the greater the opportunity for failures and attending hazards. This being the case, a plan for gross deactivation or system immunization, such as mentioned before in the specific case of one type aircraft's electrical system, or perhaps some other means that will accomplish the same objective, should be sought to be included in all future transport aircraft to simplify diagnosis of trouble.

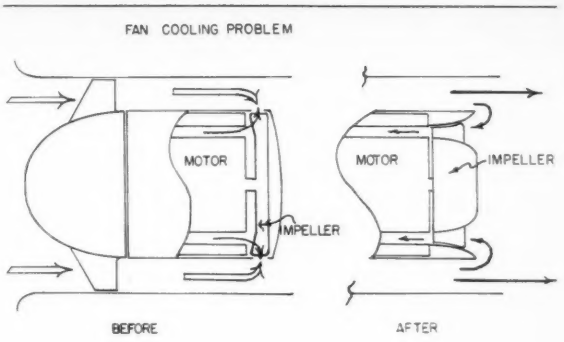
The third principle has already been touched on, but I should like to emphasize it further, and that is simplicity of design. Much has been said in the press recently about the complexity factor, its serious effect on manufacturing costs, its general adverse effect on maintenance, its contribution to delays, and its proneness to promote difficulties of trouble-shooting. All of these negative factors are unquestionably true and alone are sufficient cause to emphasize and re-emphasize simplicity. It has been my observation that it is generally much easier to design a complicated gadget or system than it is to develop a simple unit. Ordinarily the simple functional design is the result of either sheer genius or more than likely the result of tedious and time-consuming efforts that are frequently an evolutionary process from the complicated design to the simple design. Aircraft seem to stand in a complexity class all by themselves, since they include more safety devices, protective circuits, and emergency systems per cubic foot than any other public transit machine. The addition of all these safety devices does indeed provide elements of safety, but there is such a thing as compounding safety protection to the point where the overall complex design may be less safe than would be a simple, direct, unprotected but ruggedized system. There is no substitute for sound judgment based on experience in this matter, but certainly much should be said in favor of greater simplicity. In many instances greater attention to simplified design detail will do more to promote greater safety in future designs than will complicated, compounded back-up type protective systems. Rugged simplicity combined with adequate attention to detail is commended and should be encouraged. In addition to being simpler and more reliable, such designs will frequently weigh less.

Generally speaking, it would seem much better to provide simple, direct, ruggedized systems backed up when necessary by independent and simple emergency actuating systems rather than to complicate the original system design by double or triple protective devices until the basic system is so entwined with the emergency system that mechanical failure probability is multiplied because of the resulting complexity, not to mention possibilities of human failure (if it can really be called that) to cope with involved sequential gyrations or complex procedures. So-called human failure of this type is frequently the result of failure of the designer to recognize human limitations to cope rapidly with complicated interrelated functions, particularly when erroneous and sometimes incomplete information is available. Design it simple. Make it simple to operate. Make it so it cannot be incorrectly sequenced or operated. Make it so it cannot be incorrectly installed, but always strive to retain the ultimate in simplicity. By "simple" design I mean design that is uncompounded, uncombined, elementary, free from unnecessary complexity, not hard to understand, straightforward, and plain. With ever-increasing system performance demands this is not easy but will, if and to the degree attained, surely result in still safer aircraft than are operated today.

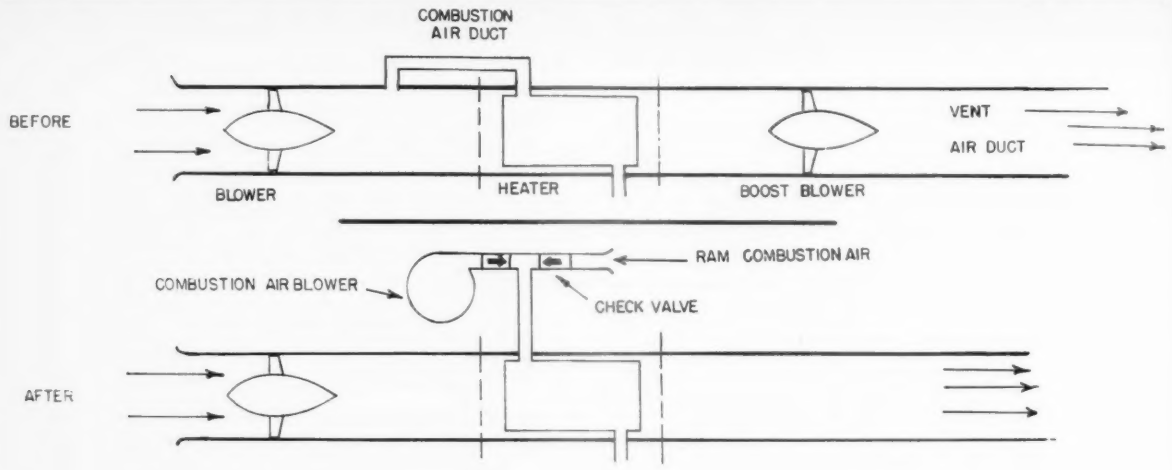
The fourth item or recommendation through which safety can be still further improved in the future is to learn more about ourselves—that is to say, the human machine and its limitations—through research and to consider the knowledge thus gained definite design parameters. While some work has been done, the complex relationship of the human to the design problem should be investigated much more thoroughly. For example, we should try to determine human behavior when stimulated by sets of adverse circumstances to determine better the action that can reasonably be expected when mechanical failures under certain critical conditions occur. It is time we pursued human re-

search with the same zeal that is typical of such items as structural or power-plant research. The flight simulator arranged to represent designs of systems under study would seem to be a very good vehicle by which design philosophies could be explored and evaluated in terms of human response and limitations under both normal and emergency conditions. This is but one of a number of practical avenues of approach open to gaining more information; however, the real point I wish to make here is that ultimate absolute safety can be developed best if designers can, in the future, more reliably tailor their designs to the human and his natural limitations.

The next point I should like to make is that great use of mock-ups and prototype design testing is helpful during the development stage. Air lines have encountered and have had to overcome unsatisfactory conditions which with but a modest amount of additional testing or testing under conditions more representative of actual operations could have been avoided. I am sure most of us can agree that it is usually cheaper and more prudent to correct design deficiencies prior to, and not after, placing the article into production. Not long ago a manufacturer of a relatively new transport corrected an inadequate airflow problem in the airplane's heating system by adding a second ventilating blower downstream of the heater. The combustion air supply into the heater was taken from a point in the ventilating air duct upstream of the heater. This worked well until certain exigencies arose in which the upstream ventilating blower failed and the added blower continued to run. This caused a suction at the combustion air take-off which pulled smoke into the ventilating airstream. Had this system originally been more adequately mocked up, the basic inadequate airflow condition that led to the installation of the second blower would have been discovered and corrected. Further, solution to the problem would not have been limited by the existence of the finished article which required a rapid operational change but would have been solved pretty much as was finally done anyway. The final arrangement accomplished when the airplane was in service incorporated a completely independent combustion air system and eliminated the additional blower by cleaning up the original duct system, decreasing the pressure loss that had originally required the additional blower. Many design deficiencies can be engineered out during development by use of detail mock-ups suitable for not only determining system performance but safety aspects as well by rational simulation of component failures. In a case in point a blower was overheating, failing after only a few hours of operation, the final stages of failure being accompanied by large quantities of smoke. Investigation revealed that the cooling fan in the motor was opposing the airflow required for cooling. The result was that the motor simply was not being adequately cooled and, of course, failed. The cooling fan was reversed and the problem thus solved. This difficulty could easily have been determined with more complete working mock-ups during the development stages. Needless to say, the existence of smoke, even though the cause may not mechanically impair flight safety, can lead to worried action which like false warnings is not necessarily in the best interest of safety. Other examples could be cited, but I trust the two examples given will serve to illustrate the point that, while mock-ups have been used extensively in the past, safety can be better ensured through still more extended use of them in the future. One of the leading English manufacturers developed a complete working mock-up to aid in the development of a very large four-engined, turboprop-powered transport. This is a metal mock-up and is virtually a complete airplane except for outboard wing panels and portions of the tail surfaces. It is complete including airplane structure, airplane systems, power plant, landing gear, etc. This company made use of the mock-up for design and system performance verification. Considerable engineering time was saved by using the mock-up to check out hydraulic plumbing runs, separation of hydraulic tubing from electrical wiring, integration and separation of system components, maintenance accessibility, system performance, and unit reliability. The mock-up was retained following prototype development and is now used as an aid to making changes and improvements in design necessitated by the availability of new products, further service experience with the aircraft, etc. Through use of this mock-up many not-so-obvious faults were discovered and resulting design improvements incorporated in the prototype airplane. The advantages to this method of expediting design are so obvious that it is rather surprising that wider use of the complete metal mock-up has not been made. Also, much can be said in favor of use of extensive mock-ups for improving and substantiating emergency system design, as well as determining compatibility of each system with the other. Controlled tests of power-plant installation fires employing the fire-extinguishing system definitely would answer many questions better than regulations and printed material.



The next point I wish to make is that safety requires that the greatest degree of system segregation should be provided in designs. All fluid, plumbing, and accessories should be completely isolated from ignition sources and should be sufficiently far away from electrical wiring to preclude the possibility of shorted wires burning



through the plumbing lines or from fluid leaking, dripping, or flowing onto electrical devices. Reasonable system and component segregation should be made one of the manufacturer's primary design criteria at the outset. The Douglas DC-2 and DC-3 were provided with plumbing tunnels forward of the wing and along the fuselage, available from the exterior of the airplane. These tunnels contained most of the plumbing runs in these parts of the airplane and isolated them from the rest of the airplane. Some of the DC-3's recently retired are believed still to have some of the original plumbing in these tunnels. This feature provided complete segregation, ease of maintenance, and protection from attrition from maintenance personnel. Fuselage pressurization complicates designs of this type; however, there are many obvious and important advantages to complete segregation. Any thinking that system segregation is not important, if noninflammable hydraulic fluids are carried, should be discouraged because noninflammability is entirely a matter of definition and degree. At the same time we should not discourage but should definitely encourage the development of still more practical "noninflammable" hydraulic fluids for use in new aircraft which are also suitable for use in currently operated aircraft. The main principle we should hope to achieve with system and component segregation is isolation of or, if you prefer, reduction in probability of compounding any hazards that may arise. It is important that mechanical failures, for example, drive shafts, do not tear out plumbing or wires or accessories if they fail. It is important that if a fluid line should fail, the fluid would not be discharged into an area where ignition could occur. It is important that smoke hazards, particularly in pressurized aircraft, be held to an absolute minimum by special consideration of materials used. It is important that every reasonable attention be given to isolation of any hazard which can reasonably arise.

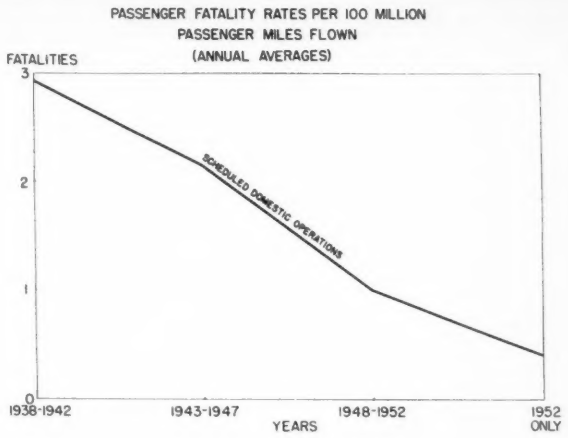
In some locations in the airplane, complete system segregation is of course difficult, such as in the powerplant installation that must be a mixture of electrical and mechanical, hydraulic, fuel, and oil systems. In these cases it is important to see that area segregation is complete and the segregation will be maintained as long as possible under emergency conditions. Flexible or extensible seals should be provided so that cowling can be deformed and still maintain the needed seals. Fuel systems should always be segregated so mechanical damage in one locality will not incapacitate another engine. Major fuel system appliances, such as strainers, should be suitably located or protected. Shut-off valves at the fuel tanks should be provided in addition to firewall shut-off valves and should be capable of positive actuation by the crew—one tank at a time or in combination. Sufficient component isolation so as to minimize the effect of progressive failure is necessary. For example, use of engine oil to drive cabin superchargers can result in contamination of the engines from supercharger failure or vice versa. Complete system segregation may, of course, never be achieved. However, past experience clearly shows the desirability of very great system segregation.

For the next item I should like to make a plea for maintaining reasonable structural conservation in future designs. Use of fatigable materials is a trend that we should question. Unless the application of such materials is well studied and unless the detail design of parts takes into account greater inherent susceptibility to fatigue, we do ourselves a disservice. Such materials should be used conservatively and only in locations not subject to shock or tension loads. I would hate to see load factors and margins of strength reduced in future designs compared to what we have experienced in the past just because experience indicates that the basis used in the past has been good. Indeed, one might be inclined to think that load factors should perhaps be raised in the future somewhat because of the increasing importance of dynamic loads as speed increases. It is perhaps not necessary to point out that as yet there has been no high utilization service with new type high-speed, turbine-powered commercial aircraft. Such aircraft will have certain structural advantages and per-

haps disadvantages compared to present aircraft. For example, I doubt if we yet know the effect, if any, of the high-frequency, low-amplitude vibration on the air frame, nor are we perhaps fully familiar with local accelerations and structural loading due to dynamic responses when flying at high speed even in mild turbulence, nor should we lose sight of the latest data which indicate that, while the frequency is less, gust intensity is not necessarily less at high altitudes than at low altitudes. While the probability of encountering high-intensity gusts at high altitudes is less than at lower altitudes, this does not necessarily ensure maintaining reasonable structural margins unless those margins are proportionately compatible with loads involved when encountering gusts, however infrequent, at higher speeds and altitudes. This whole point can be summed up as a plea for structural conservatism and for use of ductile materials.

Crashworthiness versus airworthiness is certainly a big subject. I think most will agree that the first job of any designer or manufacturer in building for greatest safety is to provide the greatest practical degree of airworthiness for the crew and passengers. It is far more important to build an airplane so that it will not encounter trouble than it is to make it so it meets trouble well. On the other hand, there are many features of design which can provide in the overall interests of safety reasonable crashworthiness without sacrifice of airworthiness features. These should be provided to the maximum extent possible. Such things as elimination of sharp objects with which the body can come in contact, elimination of the possibility of doors or panels becoming missiles in the event of sudden depressurization, adequate retention of accessories such as fire extinguishers, first aid kits, and the like so they cannot be torn loose, special attention to detail design features of seats such as softening the impact of the seat backs, the providing of deformable seat armrests and the like are important considerations. Current research in the crashworthiness field is believed most commendable and should continue. We should never lose sight of the primary objective of good commercial aircraft design, however, which is to make the airplane safe and reliable so that minimum cause for trouble will develop.

Emergency evacuation is closely related to crashworthiness. Considerable progress has been made in this field and should be continued. For example, passenger evacuation chutes that do not require support by hand at the ground would help. Location and size of emergency exits or doors is certainly a suitable subject for constant attention. The same is true of means for getting from a window type exit to the ground. Additional tests and research on this subject should continue.



The subject of airplane design in relation to safety has been barely touched upon here. There are many additional points that could be treated.

In conclusion, I should like to make one more point on safety and that is the extreme importance of keeping the draftsmen, the detailers, and the designers fully informed with respect to service experience. While airplane manufacturers universally attempt to accomplish just this, I should like you to remember that many of our difficulties are due to details as contrasted with major structural or component difficulties.

I should like to say again that the excellent safety record obtained by the U.S. air carriers through industry efforts at large, including the manufacturers and federal officials as well as air-line personnel, is a record that we must proudly protect at all times and constantly strive to improve in the future. This can best be done by constant review of past operating experiences coupled with continuing and expanding research activities.

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(See page 122 of this issue.)

Economic Considerations of the Transport Helicopter

JAMES B. EDWARDS*

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ABSTRACT

This paper traces some of the basic rules by which the commercial air transport industry has achieved its present standards and relates these to the present status of the helicopter in commercial transport planning.

As an approach to the basic economic problem involved (will the allowable passenger fare permit a profitable operation), an example of helicopter versus DC-3 operation is analyzed. In this analysis, the intercity operation emerges as a logical first step to establish working rules for designers and operators, and the $6,000 per year man points the way to a passenger fare level.

DISCUSSION

OF THE 25 YEARS I have enjoyed in aircraft engineering, roughly half have been devoted to aiding the development of transport airplanes.

During this period, I have been privileged to witness the efforts put forth by manufacturers, operators, and Government agencies to bring our national and international air transport systems to their present high standards.

The precepts by which these groups are guided have been, and still remain, *safety*, *comfort*, *speed*, and *economy*. In a private enterprise operation, no transport airplane has been a success without improving these qualities over those of its predecessor.

Since all these qualities are relative rather than absolute, a base had to be established by early experience and then improved on by repetitive steps of *scientific development*, *public acceptance*, and *operational profit*. While I do not attempt to minimize the headaches that went into this process, I think it may be safely maintained that, in essence, this has been an orderly development in which the fundamental rules were well known to all concerned.

During the past 2 years, I have concentrated exclusively on helicopters and have listened to and have read thousands and thousands of words spoken and written about the developments and prospects of this industry. I am sure all of you with whom I have talked in the last 2 years recognize the extent of my interest in this form of transportation, but even with all this enthusiasm, I cannot help but feel deep concern at the measure of optimism shown in most of these thousands of words.

Up to this point, by comparison with the fixed-wing transport industry, there has been a tremendous *public acceptance* (of an idea)—a very substantial *scientific development* (of military machines)—*and no profit*.

The public acceptance has been engendered by many wonderful and worth-while things—the medical evacuation operations in Korea and Indo-China; the Netherlands flood aid activities; the Navy and Coast Guard sea rescue missions; the clockwork operations of New York Airways, Los Angeles Airways, and Chicago Air Services; and the demonstrations of helicoper capabilities brought to groups all over the country by such industry representatives as Joe Mashman, of Bell Aircraft. It is only natural for John Q. Public, after seeing these things, to envision his own simplified transportation from Bremerton to Seattle, or Catalina to Los Angeles, or Mineola to Manhattan, and he is absolutely right except that neither the manufacturer nor the operator has any ground rules by which they know how to satisfy this unfilled public demand.

As I said before, safety, comfort, speed, and economy are relative terms. When we talk of the transport helicopter, we can relate safety and comfort to the standards of transport airplanes and thus have a measure. When we talk of speed and economy, we are comparing with trains, busses, taxis, and all forms of surface transportation, or to transport airplanes in combination with the surface vehicles. This, it seems to me, is not a very solid footing until a measure of public acceptance against the tariff required has been obtained.

Now, in most of the literature on helicopter passenger operations, three spheres of operation are generally considered: the airport to city-center service, the commuter service, and the local service type operation now accomplished by fixed-wing aircraft.

Of these three, it would seem that the first two, while of great eventual benefit to both tempers and living habits, are beset by so many operational and economic problems, such as rate structure, baggage handling, helicopter utilization, heliport locations, noise level effects, etc., that they may lag behind the local service type operation that basically replaces an existing airplane on an existing air service with a nonexistent helicopter.

As manufacturers of by far the greater majority of all transport aircraft operating the world today, the Douglas Aircraft Company has an inherent interest in this new field. As builders of the DC-3, still the standard workhorse of the world's air-line fleet, we have a particular interest in any vehicle that might economically replace this aircraft.

One need only review the numerous attempts that have been made in the past 10 to 15 years to produce

Presented at the Rotating Wing Aircraft Session, Twenty-Second Annual Meeting, IAS, New York, January 25–29, 1954.

* Chief Project Engineer, Special Projects, Santa Monica Division.

a more economical vehicle than the DC-3 to realize that it is a difficult criterion to meet. I am sure that other aircraft manufacturers must have often come to the same conclusions that we have reached in our numerous design studies of a fixed-wing "DC-3 replacement":

(1) Considering the average trip lengths that the DC-3 is now called upon to fly, there is little advantage in having a substantially higher cruising speed.

(2) Considering the traffic density of the routes the DC-3 is flying, the inherent economies of a substantially larger aircraft cannot be realized and at the same time maintain an acceptable level of flight frequency.

(3) Increased labor and material costs would raise the price of the DC-3, if built today, to three or four times its initial selling price and to several times the surplus or present-day market value.

As a result of these conclusions, coupled with the fact that today's reciprocating engines show little or no improvement in fuel economy over those presently being used in the DC-3, it can be appreciated that little, if any, increase in economy can be expected from a conventional fixed-wing aircraft for the short-haul market. It is for this reason that we are studying the commercial helicopter to see whether it offers a solution to this problem.

This market will service those persons now being transported domestically in the United States by DC-3's or in Convair and Martin equipment, in addition to travelers currently using surface transportation.

The economic position of the local service carriers is ample evidence of the high costs incurred in short-haul air transportation.

The local service carriers have not been singled out here for the purpose of criticism but only to demonstrate the inherently high costs that are associated with short-haul transportation. Many of the domestic trunk lines conduct operations that are basically similar in characteristics to those operated by the local service carriers, and were it not for the profitable long-haul operations their income statements would reflect the same conditions. The local or feeder air lines have made tremendous strides in reducing their mail pay need since their certification. However, I am sure that they will agree that with their present equipment their chances of obtaining economic self-sufficiency are still many years off. I am also certain that these air lines are unanimously in agreement that they cannot achieve this hoped-for goal by increasing their fare levels with present equipment. The result of this latter adjustment would be to drive a much greater proportion of the present air travelers back to using a surface means of transportation and, hence, losing more revenue than would be gained from the higher fares charged the remaining passengers.

From this qualitative line of reasoning one might conclude that there is little or no future for short-haul air travel, since it does not appear that costs can be reduced or fares increased sufficiently to offset the present levels of subsidy that are required.

Moreover, as a great many studies have indicated, the time when a helicopter can compete costwise with a DC-3 is many years into the future. These studies have all concluded that such a helicopter must have somewhere between 40 and 60 seats to compete with a depreciated DC-3. It will be many years before the short-haul air transportation industry will be able to absorb a vehicle of this size. The present DC-3 load factor in local service is in the neighborhood of 40 per cent, and, in most cases, the flight frequency is already at the minimum acceptable level. From this, it may be concluded that the helicopter's economic characteristics will do little to alleviate the previously noted high cost of short-haul air transportation.

Therefore, it appears that, if the helicopter is to better the economics of this type of traffic, it must do so by increasing the revenue portion of the profit and loss statement. If the service can be made more attractive by increasing the overall city-center to city-center speed or convenience, the unit fare structure can be increased because the air-line operator will be selling a better product. The best economic balance between these two factors will not be known until actual operations are well under way, but it is obvious that even the better product will not be salable at too great an increase in cost.

Tables I and II indicate the extent that fares might logically be increased.

Table I represents the timesavings possible between the DC-3, operating from present airports, and a similar sized helicopter operating out of the metropolitan area. The particular condition shown here represents a 200-mile passenger journey, wherein the aircraft makes two en route stops between the passengers' origin and his destination. While this represents the average condition prevailing for the local service carriers, it is believed indicative of the conditions that would also prevail on the "local service type" routes of the major trunkline carriers.

Analysis of limousine travel time, between various city-centers and their fixed-wing airports, indicates that an average of 45 min. for a one-way trip can normally be expected. Since the helicopter will not operate from the top of every office building or hotel, it has been assumed that an average of 10 min. would be required for the passenger to arrive at the heliport via taxicab or other surface means.

The waiting time at the airport prior to departure has been assumed to be equal for both the fixed-wing aircraft and the helicopter on the basis that a minimum amount of check-in time will be required for both vehicles. Once aboard the aircraft, an allowance must be made for warm-up and ground maneuver time, in addition to the time lost during climbing operations. It was conservatively assumed that the helicopter ground time would be one-half that required for the conventional aircraft. The cruising time shown is

TABLE I

TIME SCHEDULE

200-MILE PASSENGER JOURNEY WITH TWO ENROUTE STOPS

ITEM	DC-3	HELICOPTER
	MINUTES	
City Center to Airport	45	10
Airport Waiting Time	10	10
Origin Ground Maneuver and Climb Allowance Time	8	4
First Segment Cruise Time	23	27
First Enroute Stop		
Ramp Time	4	4
Ground Maneuver and Climb Allowance	8	4
Second Segment Cruise Time	23	27
Second Enroute Stop		
Ramp Time	4	4
Ground Maneuver and Climb Allowance	8	4
Third Segment Cruise Time	23	27
Destination Airport Waiting Time	0	0
Airport to City Center	45	10
Total Time (Minutes)	201	131
(Hours)	3.35	2.18
Difference (Hours)	1.17	

based on a cruising speed of 173 m.p.h. for the DC-3 and 150 m.p.h. for the helicopter. Since the ground maneuver and climb allowance time has been provided for in the previous value, the cruise times are merely the distance divided by the cruise speed.

The en route stop time assumes that the ramp time will be equal for both types of aircraft, since they have the same seating capacity. The destination waiting period would ordinarily be that time consumed in obtaining baggage; however, since it is assumed that the carry-on provisions are available in both types of equipment, this waiting time will be nil.

It will be noted from the total values for the two types of equipment that the DC-3 operation requires 3 hours and 21 min. compared with 2 hours and 11 min. for the helicopter, a reduction of 35 per cent in overall trip time. The average block speeds for the DC-3 and helicopter, including ground time, are 60 and 92 m.p.h., respectively.

Table II represents a brief analysis of the economics of the two types of operation. In this table the present DC-3 is compared with a "new" DC-3—i.e., one having an initial cost of approximately $350,000—and a 28-passenger helicopter.

The direct operating cost for the present DC-3 represents the average value realized by the domestic air lines for the year 1952. The value for the "new" DC-3 represents the present DC-3 value adjusted for the higher initial cost. The value for the 28-passenger helicopter has been estimated from trend studies on current and proposed helicopters and is assumed to represent a value obtainable at the 1965 level of development.

The indirect operating costs are approximately equal to those of the major trunkline carriers and are not to be confused with the considerably higher values currently realized by the local service operators. Since we are approximating the conditions of the "local service type" routes of the trunkline carriers, this assumption appears valid. A constant value for indirect operating costs for the two types of equipment has been assumed, since any reduction in sales, ticketing, or other passenger amenities expense that can be realized on the helicopter can, for the most part, also be realized by the operator of fixed-wing aircraft if desired.

The air-line fares shown in the first three columns represent the basic 6-cent fare level adjusted for family plan and round-trip discounts. The 5.7 cents, therefore, indicates the average yield to the carrier and the average ticket expense to the passenger. The dollar outlay for the 200-mile trip would then be $11.40. Adding to this the average city-center to airport limousine fare of $1.25 each way results in a total expense for the trip of $13.90 or represents an overall effective fare of 6.95 cents per mile. The second column is identical to the first with the exception that the direct operating costs have been increased to allow for the higher depreciation charges resulting from the higher initial cost of the aircraft. The dilemma of the local service carriers who rely on this type of traffic exclusively is readily apparent. In the case shown, the increased direct costs are sufficient to turn a profitable operation into a losing one.

Three different fare conditions are evaluated for the helicopter. The first represents the same fare level as used for the fixed-wing aircraft. Since the $1.25 limousine fare at the end of the fixed-wing aircraft trip has now been reduced to a 50-cent taxicab fare, the passenger is actually paying a lower overall fare than he would on the conventional aircraft. The resultant operating loss is apparent. The second helicopter column represents the condition where the total air and ground fare remains the same for the two types of aircraft; but since the ground fare is less for the helicopter, the air fare can be correspondingly increased. It will be noted that a loss will still result. The third condition is an indication of the fare that would have to be charged if the new 28-passenger helicopter must yield the same net operating income as the present DC-3 before it will replace the latter aircraft. Under these circumstances, the air-line revenue must exceed the total operating cost by 0.4 cent per passenger mile. This condition results in an air-line ticket fare of $16.40 or an overall fare of $17.40.

The $3.50 difference between the total helicopter fare and the total DC-3 fare represents a cost of $3.00 per hour saved. This is equivalent to the hourly salary of the person receiving $6,000 annually. Therefore, since in most cases a trip of this length would be made during a working day, it would behoove a businessman making $6,000 or more per year to take advantage of this timesaving. While it is not suggested that this calculation be used for future rate-making purposes, it is believed it adequately reflects what we mean when we say a better product can command a better price.

Obviously, if a larger helicopter can be utilized at the same load factor without hampering the frequency of

TABLE II

EFFECT OF FARE STRUCTURE ON THE RELATIVE ECONOMIES OF THE DC-3 AND A SIMILAR SIZED HELICOPTER

Item	Present DC-3	"New" DC-3	28-Passenger Helicopter		
			1960-65		
Costs					
Direct Operating Cost (Cents/Passenger-Mile @ 65% Load Factor)	2.3¢	3.2¢	~ 4.8¢		
Indirect Operating Cost (Cents/Passenger-Mile @ 65% Load Factor)	3.0¢	3.0¢	3.0¢		
Total Operating Cost (Cents/Passenger-Mile)	5.3¢	6.2¢	7.8¢		
			(A)	(B)	(C)
Revenues					
Airline Fare Cents/Passenger-Mile	5.70¢	5.70¢	5.70¢	6.45¢	8.20¢
Dollars for 200-Mile Trip	$11.40	$11.40	$11.40	$12.90	$16.40
City Center to Airport Fare 2 X $1.25	$ 2.50	$ 2.50			
2 X $0.50			$ 1.00	$ 1.00	$ 1.00
Total Trip Cost	$13.90	$13.90	$12.40	$13.90	$17.40
Effective Overall Fare (Cents/Passenger-Mile)	6.95¢	6.95¢	6.20¢	6.95¢	8.70¢
Net Income (Cents/Passenger-Mile)	+0.40¢	-0.50¢	-2.10¢	-1.35¢	+0.40¢
Cost Difference for Trip			$-1.50	0	$ 3.50
Time Saved			1.17		
Cost Per Hour Saved			-	-	$ 3.00
Equivalent Annual Income 2,000 Hours/Year			-	-	$6,000

operation, rates can be reduced below the levels indicated here. As a result, the service will appeal to even lower income groups and air travel on the whole will penetrate further into the present surface transport market.

This little study, for which I wish to thank William Crilly of our company, offers a basis for one economic solution of the helicopter transport problem and is presented with the hope of stimulating discussion and further study leading to a set of ground rules.

To us it appears conservative, since, to the best of our knowledge, all improvements in travel have generated additional traffic, and this factor could well be the means by which intercity air travel could become self-supporting.

In this sense, an economic justification of substantial magnitude is added to the great sociological and defense benefits that may be anticipated by strong and consistent support of helicopter development and operations.

In conclusion, I should like to offer my respects to the small series of multiengined helicopters which are either in, or about to be in, the development flight stage. These aircraft, given the opportunity, can fire what I believe to be the opening gun in helicopter transport operations by creating the base on which the essential steps of scientific development, public acceptance, and profitable operation may be founded.

IAS News

(*Continued from page 37*)

outstanding achievements in the aeronautical field and for the friendly cooperation given to the Italian authorities in the difficult task of developing a common program of aircraft production in Italy."

▸ **Colonel C. R. Laubenfels,** USAF (Ret.) (M) recently retired from the U.S. Air Force and is now teaching Aeronautical and Mechanical Engineering at the Los Angeles City College. Colonel Laubenfels was formerly with the Wright Air Development Center at Wright-Patterson AFB, Ohio.

▸ **Maitland McLarin** (TM), is now Group Leader—Engineering, Naval Air Navigational Electronics Project, NATC, NAS, Patuxent River, Md. He was formerly Assistant Product Engineer, Bombardment Engineering Department, Sperry Gyroscope Company, Division of The Sperry Corporation.

▸ **R. T. Nalle, Jr.** (M), Manager, Production, Aviation Gas Turbine Division, Westinghouse Electric Corporation, has been sent by Westinghouse to the Harvard Business School, Harvard University. He will remain there for $1^1/_2$ years.

▸ **Dr. G. B. Schubauer** (F), formerly Chief, Aerodynamics Section, National Bureau of Standards, has been appointed Chief of NBS's New Fluid Mechanics Section. This new section is covering the work formerly carried out in the Aerodynamics and Hydraulics sections. The work remains in the Mechanics Division. Dr. Schubauer was the co-winner of The Sylvanus Albert Reed Award for 1947.

▸ **Juan T. Trippe** (AM), President, Pan American World Airways, Inc., is now serving as Chairman of the Aviation Division of the Committee of American Industry. A division of the National Fund for Medical Education, the C.A.I. is spearheading a nationwide appeal to raise $10,000,000 for the country's 79 medical schools.

Members on the Move

The purpose of this section is to provide information concerning the latest affiliations of IAS members. All members are, therefore, urged to notify the News Editor of changes as soon as they occur.

Krishin P. Abichandani (TM), Design Engineer, Air Armament Section, Electronics Division, Canadian Westinghouse. Formerly, Aerodynamics Engineer, Canadair Limited.

Alden E. Acker (M), President and a Director, Hycon Manufacturing Company. Formerly, Vice-President and a Director, Hycon Manufacturing Company.

Ensign F. M. Anderson, USN (TM), Assistant Project Officer, U.S. Naval Ordnance Missile Test Facility, White Sands Proving Grounds, N.M. Formerly, Student, U.S. Naval Officer Candidate School, Newport, R.I.

Donald P. Armstrong (M), Assistant Project Engineer, Northrop Aircraft, Inc. Formerly, Assistant Chief Engineer, General Representative, Western District, Bureau of Aeronautics.

G. L. Bergst, Jr. (TM), Associate Engineer, El Segundo Division, Douglas Aircraft Company, Inc. Formerly, Maintenance Officer, Marine Aircraft Maintenance Squadron 33, 1st Marine Air Wing, c/o FPO, San Francisco.

Rear Admiral Calvin M. Bolster, USN (Ret.), FIAS, now Coordinator of Development, The General Tire & Rubber Company, Akron, Ohio. Formerly, Chief of Naval Research, USN. (For details of retirement, see page 41, March issue, AERONAUTICAL ENGINEERING REVIEW.)

Allan Chilton (F), Chief Engineer, Aviation Gas Turbine Division, Westinghouse Electric Corporation. Formerly, Director, Experimental Operations, Wright Aeronautical Division, Curtiss-Wright Corporation.

Dean G. Cumro (M), Research Engineer, Georgia Division, Lockheed Aircraft Corporation. Formerly, Structures Test, Materials and Processes, B-O-P Assembly Division, General Motors Corporation.

Howard I. Dwyer, Jr. (TM), Junior Engineer, Design Group, Guided Missiles Section, Bendix Products Division, Bendix Aviation Corporation. Formerly, Active Duty, USAF, 1st AACS, I&M Sq., Tinker AFB, Okla.

Willis M. Hawkins (M), Chief Engineer, Missiles System Division, Lockheed Aircraft Corporation. Formerly, Chief Preliminary Design Engineer, Lockheed.

E. H. Higgins (M), Chief Project Engineer, Engineering Department, Canadair Limited. Formerly, Administrative Engineer, Canadair.

Second Lieutenant John C. Hilton, USAF (TM), 3303 Pilot Training Squadron, Bartow AFB, Fla. Formerly, Aeronautical Engineer, Allied Research Associates, Inc.

Earl R. Hinz (M), Aerodynamics Engineer "A," Ryan Aeronautical Company. Formerly, Senior Aerodynamics Engineer, Consolidated Vultee Aircraft Corporation.

Bennett H. Horchler (AM), General Manager, *Applied Hydraulics*, Cleveland, Ohio. Formerly, Assistant Publisher, *Skyways*, New York.

Martin V. Kiebert, Jr. (M), Chief Engineer, Tuner Division, P. R. Mallory & Company, Inc. Formerly, Director, Special Products Research Department, Bendix Aviation Corporation.

W. W. White, AFIAS, a Vice-President, Director, and General Manager of the Aviation Department, Esso Export Corporation, has been granted a leave of absence and is now serving as Staff Director for Petroleum Logistics, Department of Defense. He is working directly under C. S. Thomas, Assistant Secretary for Defense (Supply and Logistics). Mr. White's appointment, which is for 1 year, began on February 8, 1954.

Charles E. Kitsmiller (AM), Quality Manager, Metals Processing Division, Curtiss-Wright Corporation. Formerly, Production Engineering Manager, American Car & Foundry Company.

Robert G. Loewy (M), Staff Technical Assistant to the Head, AeroMechanics Department, Cornell Aeronautical Laboratory, Inc. Formerly, Staff Stress Engineer, Piasecki Helicopter Corporation.

Walter H. Lowe (TM), now Design Engineer "B," Georgia Division, Lockheed Aircraft Corporation.

Edward T. Martin (TM), Superintendent of Training, Flight Safety, Inc. Formerly, Flight Instructor, Flight Safety, Inc.

Arthur Nutt (F), Vice-President—Engineering, Lycoming Division, Avco Manufacturing Corporation. Formerly, Director of Engineering and Contracts, Bridgeport-Lycoming Division, Avco Manufacturing.

Donald E. Power (TM), Undergraduate Student in Aeronautical Engineering, University of Michigan. Formerly, Junior Designer, Goodyear Aircraft Corporation.

Hiroshi Sato (TM), Institute of Science and Technology, University of Tokyo, Japan. Formerly, Research Assistant, Polytechnic Institute of Brooklyn.

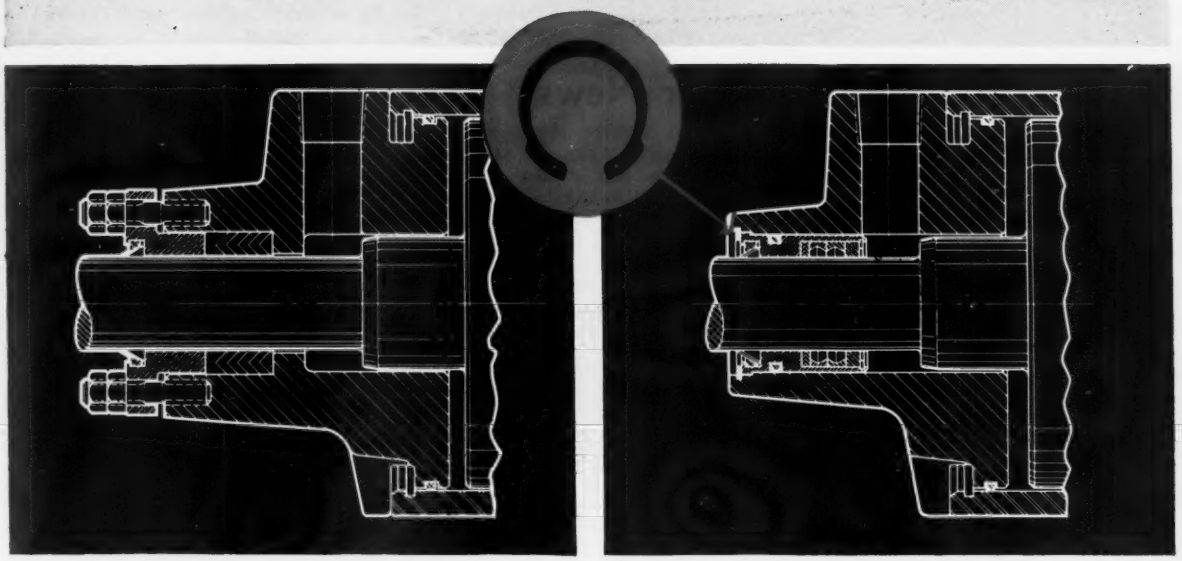
Everett B. Schaefer (AF), Assistant Chief Engineer, Canadair Limited. Formerly, Chief Technical Engineer, Canadair.

L. Grant Snyder (M), now Director of Customer Relations, Electronic Products Corporation.

Lucien A. Schmit, Jr. (TM), with Aero-Elastic Laboratory, Massachusetts Institute of Technology. Formerly, with Chance Vought Aircraft, Inc.

Payson S. Tseu (M), Preliminary Design Aerodynamicist, Pastushin Aviation

Waldes Truarc Ring Saves $2.84 Per Unit, Cuts Labor-Time and Materials in Hydraulic Packing Unit



OLD STYLE stuffing box required skilled worker to install packing rings one at a time, then adjust packing glands by trial and error. Disassembly was equally difficult, time-consuming and costly.

NEW Monopak Cartridge is smaller, lighter, streamlined and installed with one Truarc Retaining Ring. Disassembly and reassembly with new cartridge takes unskilled worker just 1 minute.

Hydraulic Accessories Company of Van Dyke, Michigan, uses a single Waldes Truarc Inverted Ring (internal series 5008) to hold Monopak Cartridge in cylinder head.

New design eliminates costly machining and saves 2⅛ lbs. of material. Re-design with Waldes Truarc Retaining Ring reduces stuffing box diameter from 3½" to 2⅞", and reduces length from 5⅞" to 4⅜". Allows savings in assembly, adjusting and testing.

NEW DESIGN USING WALDES TRUARC RING PERMITTED THESE SAVINGS PER UNIT

MACHINE TIME SAVED:	
Chucking, facing and boring	$ .72
Drilling and tapping 3 holes	.18
Drilling and counterboring 3 holes	.12
Assembling, adjusting, testing	.90
MATERIAL SAVED:	
1½ lbs. cast iron	.30
½ lb. bronze	.23
3 studs	.36
3 nuts	.03
TOTAL	**$2.84**

Waldes Truarc Retaining Rings are precision-engineered . . . quick and easy to assemble and disassemble. Always circular to give a never-failing grip. They can be used over and over again. There's a Waldes Truarc Ring to answer every fastening problem.

Find out what Waldes Truarc Retaining Rings can do for you. Send your blueprints to Waldes Truarc engineers for individual attention, without obligation.

For precision internal grooving and undercutting . . . Waldes Truarc Grooving Tool. See the Waldes Truarc exhibit at the A.S.T.E. Show, April 26-30. Booth No. 424, Precision Hall.

SEND FOR NEW CATALOG

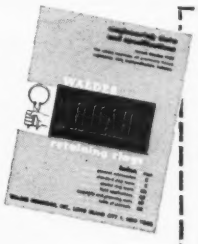
WALDES TRUARC

REG. U. S. PAT. OFF.

RETAINING RINGS

WALDES KOHINOOR, INC., LONG ISLAND CITY 1, NEW YORK

WALDES TRUARC RETAINING RINGS AND PLIERS ARE PROTECTED BY ONE OR MORE OF THE FOLLOWING U. S. PATENTS: 2,382,947; 2,382,949; 2,416,852; 2,420,921; 2,428,341; 2,439,785; 2,441,846; 2,455,165; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,509,081 AND OTHER PATENTS PENDING



Waldes Kohinoor, Inc., 47-16 Austel Place, L.I.C. 1, N.Y.

Please send me the new Waldes Truarc Retaining Ring catalog. AE-046

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Corporation. Formerly, Aerodynamics Engineer, Lockheed Aircraft Corporation.

Richard R. Tumlinson (TM), Design Aerodynamicist, Chance Vought Aircraft, Inc. Formerly, First Lieutenant, USAF.

Don L. Walter (AF), Vice-President, Marquardt Aircraft Company. Formerly, Director of Engineering and Manufacturing, Marquardt.

Herbert K. Weiss (AF), Chief, Weapon Systems Analysis Department, Northrop Aircraft, Inc. Formerly, Chief, Weapon Systems Laboratory, Ballistic Research Laboratories, Aberdeen Proving Ground, Md.

Maurice I. Young (TM), Senior Vibrations Engineer, Piasecki Helicopter Corporation. Formerly, Dynamics Engineer, Bell Aircraft Corporation.

Corporate Member News

• **Air Associates, Incorporated . . .** Charles A. Sereno, formerly Chief Engineer, was elected Vice-President and General Sales Manager of the Electronic and Mechanical Products divisions.

• **Beech Aircraft Corporation. . .** Three new Beechcraft executive airplanes for 1954 were introduced at the corporation's annual U.S. distributors' meeting held at the Beech plant in Wichita, Kan., on January 28 and 29. These aircraft are: the four-place Model E35 Beechcraft Bonanza, powered by either a Continental E-185-11 or a Continental E-225-8 engine; the six-place Model B-50 Twin-Bonanza, powered by two 260-hp. Lycoming GO-435-C2 engines; and the new nine-place Super 18 Beechcraft, which is based on the Beechcraft Model 18 executive transport. The prototype of the Super 18 made its first flight on December 10, 1953; first deliveries are expected early this summer. The Super 18 has a cruising speed of 215 m.p.h. and a range of 1,455 miles. It will be powered by two Pratt & Whitney R-985 AN-14B engines, which produce 450 hp. at 2,300 r.p.m.'s at take-off power. (Picture of the Super 18 will be found on this page.)

• **Boeing Airplane Company. . .** The 500th C-97 Stratofreighter was delivered early in February to the U.S. Air Force. At the time of this delivery, it was announced that these multipurpose USAF tanker-transports have been produced at the rate of one airplane per working day since August, 1953. . .Boeing is currently modifying two Stratofreighters for installation of new Pratt & Whitney T-34 turboprop engines. The first of these newly modified aircraft will fly late this year.

• **Consolidated Vultee Aircraft Corporation. . .** On February 3, Convair announced that the B-36J is now in production at the Fort Worth Division and that deliveries to the Air Force have been begun. This new model of the B-36 differs from earlier models in that its maximum gross weight has been increased to more than 400,000 lbs. Gross weight of the previous production model was listed by Convair and the Air Force as 358,000 lbs.

• **Cornell Aeronautical Laboratory, Inc. . . .** A Cornell Aeronautical Laboratory Professorship was recently created at Cornell University, with Dr. Mark Kac, of the university's mathematics staff, as the first incumbent. This chair, it was said, may be rotated among members of the Cornell University faculty. The incumbent will spend about a month of the year at the Laboratory and the remainder of the time in teaching and research on the Cornell University campus.

• **Douglas Aircraft Company, Inc. . .** The U.S. Air Force announced on February 3 that its first four-engined turboprop transport, the 200-passenger Douglas YC-124B, has successfully completed its maiden flight. This prototype is expected to provide the Air Force with important technical data on the operation of turboprop aircraft. This ship is powered by Pratt & Whitney YT34-P-1 engines, which develop the equivalent of 5,500 hp. each at take-off. The physical dimensions of the airplane are basically the same as its predecessor, the C-124 Globemaster. Design gross weight is 200,000 lbs., and design pay load is 64,000 lbs.

• **Eaton Manufacturing Company. . .** A 14-page article entitled "A Question and Answer Discussion of Valve Gear Problems" is contained in the December issue of the *Eaton Engineering Forum*, issued by Eaton. Authored by Vincent Ayres, Assistant Chief Engineer of Eaton's Valve and Saginaw divisions, the article covers such topics as operating conditions, valves—material and design, seat inserts and tappets, and hydraulic lifters. The subjects are presented in a question-and-answer format. Many photographs are included to supplement the text. Copies of this issue of the *Engineering Forum* may be obtained gratis from Eaton's offices at 739 E. 140th St., Cleveland, Ohio. . . All of the common stock of Spring Perch Company, Lackawanna, N.Y., has been acquired by Eaton. This company, producer of chassis springs, will be operated as a subsidiary of Eaton. . .The election of new officers was recently announced. These were F. H. Mott, now Administrative Vice-President in charge of all Eaton plant operations in Michigan, and R. E. Fisher, now Vice-President in charge of sales for the corporation. R. H. Daisley, who was Vice-President—Manufacturing, is now Administrative Vice-President in charge of all Eaton plants in Ohio, Kenosha, Wis., and London, Ontario.

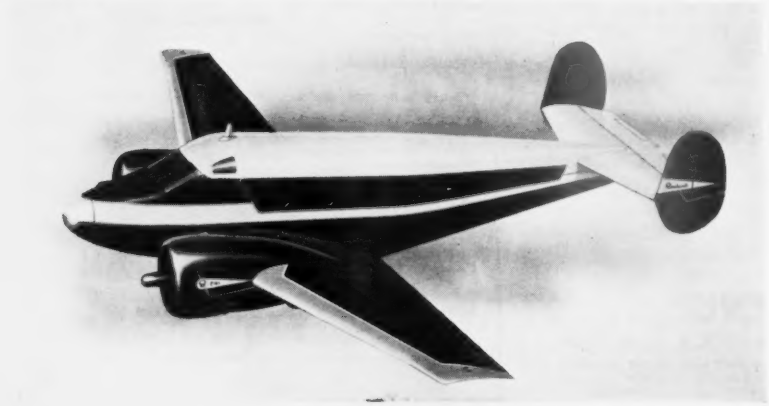
• **The Firestone Tire & Rubber Company . . .** At the recently held annual meeting of the Board of Directors, Raymond C. Firestone and J. E. Trainer were elected to the newly created positions of Executive Vice-Presidents. Mr. Firestone was formerly Vice-President in Charge of Research and Development; Mr. Trainer was Vice-President in Charge of Production. Both men were elected Directors of the company in 1942.

• **General Electric Company. . .** A contract has been let to General Electric's Aircraft Products Department to design a new armament system for the Boeing B-47 and Douglas B-66 bombers. This contract provides for increasing the potential of the present system by developing prototypes that incorporate the latest ideas and techniques. This particular contract does not include production work. . .A new bulletin, designated GET-2416, has been put out by G-E's Aeronautical and Ordnance Systems Division. This two-color booklet contains a technical description of the company's FC5 Flight Control System. It is available from the G-E Apparatus Sales Division in Schenectady, N.Y.

• **Jack & Heintz, Inc. . . .** *Bulletin No. 6014*, in which is described the company's Rotomotive Equipment for aircraft, is available on request from the Cleveland office. In this new publication are "comprehensive tabulations" that give design, performance, and application data on turbojet engine starters, reciprocating engine starters, a.c. and d.c. generators, motors, actuators, and completely integrated electrical control systems.

• **Lockheed Aircraft Corporation. . .** It was announced on February 4 that Lockheed has been awarded contracts to produce its

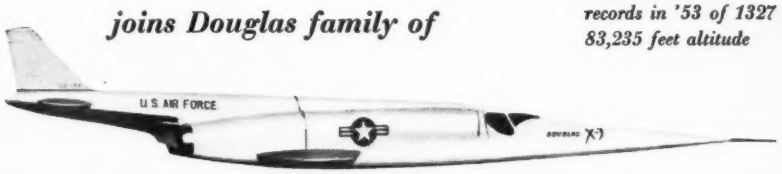
Beech Aircraft Corporation recently introduced the new Super 18 Beechcraft, shown in the photograph below. Further details of the Super 18 may be found in the Beech item on this page.



Skyrocket—set world records in '53 of 1327 mph, 83,235 feet altitude

Stiletto-shaped twin jet

joins Douglas family of



Skystreak—world speed record 1948, 650 mph

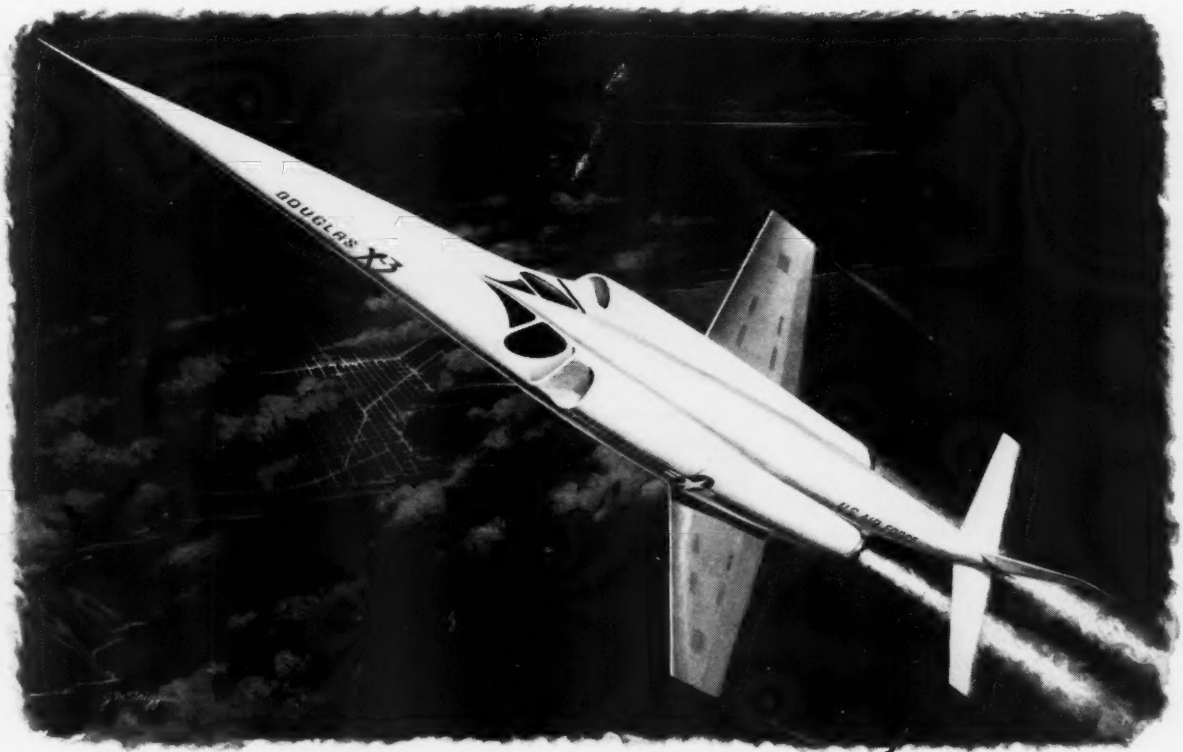
high-speed research aircraft

—the supersonic Douglas X-3

Now to the record-breaking Skystreak, the Douglas Skyrocket and the record-holding carrier-based Skyray, add this important experimental plane—the Douglas X-3.

Performance is secret, but a little can be told. Longer, heavier than a DC-3 transport, X-3 flies on wings smaller than a DC-3's tail—using conventional jet engines for *sustained* flight. X-3 has already contributed basic facts on insulation, refrigeration, and the use of heat-resistant *titanium*, while its payload of research instruments has been used to study the stresses and strains of flight at supersonic speeds.

Design of X-3 is another example of Douglas leadership in aviation. *Faster and farther with a bigger payload* is a basic Douglas rule.



Enlist to fly with the U.S. Air Force

Depend on *DOUGLAS* **First in Aviation**

This is the first photograph to be released showing Boeing Airplane Company's new four-jet transport-tanker prototype. This 190,000-lb. ship, America's first jet transport, is now nearing completion at the company's Renton, Wash., plant. Ultimately, this ship will be used as a demonstrator for both the military services and commercial air lines. As a military airplane, it will be suitable for high-speed high-altitude tanker-transport duties. As a commercial air liner, it will be capable of making regular nonstop transcontinental flights in less than 5 hours and scheduled nonstop New York-to-London flights in less than 7 hours. Depending upon the range and pay-load requirements of various operators, this new Boeing will carry between 80 and 150 passengers. An exact scale model of this prototype is pictured on this month's cover, with the accompanying caption on page 3.

new antisubmarine warfare airplane, the Neptune P2V-7. This plane, which is now in full production at Burbank, Calif., has among its identifying features a double-bubble pilot canopy for increased visibility, jet pod engines supplementing its turbocompound power plants, and an elongated tail housing electronic sub-hunting equipment. This 36-ton aircraft can be converted for patrol, mine-laying, or torpedo-bomber duty. It can be flown by one man alone on either its turbocompound engines or its jet engines, or on both types combined.

• **Marquardt Aircraft Company. . .** Two Vice-Presidents of the company were recently elected: William H. Schwebel and Don L. Walter, AFIAS. In addition to now being a Vice-President of the company, Mr. Schwebel is also Secretary-Treasurer of Marquardt. Mr. Walter was formerly Director of Engineering and Manufacturing.

• **The Glenn L. Martin Company. . .** A 38-page brochure that presents background data on the systems engineering philosophy and details its more important applications at Martin has been prepared for those persons closely identified with aircraft building. Copies are available, on request, to interested industry executives and engineers.

• **McDonnell Aircraft Corporation. . .** According to a February 8 announcement by the USAF Air Research and Development Command, the XV-1 convertiplane, the first military aircraft of this type ever developed in the United States, was rolled out of the McDonnell hangar at St. Louis. The convertiplane, a joint development of ARDC, USA Transportation Corps, and McDonnell, is designed to carry three passengers or two litter patients and a medical attendant in addition to the pilot. The craft is approximately 30 ft. long and 10 ft. high; it spans 26 ft. in width. Each of the three blades of the rotor is powered by a McDonnell-developed pressure jet unit located at the tip of the blade. A reciprocating engine, manufactured by Continental Motors Corporation, is provided on the aft fuselage to supply air to the pressure jet units during vertical flight and power to the propeller during forward flight. The primary function of this craft is the exploration of the application of the convertiplane principle to larger aircraft. Studies are also to be made on the tactical military use of the convertiplane for reconnaissance and other related missions. The first actual flight is not expected to take place until next summer.

• **Minneapolis - Honeywell Regulator Company. . .** A new electronic instrument incorporating three complete measuring and balancing circuits automatically measures two variable conditions and simultaneously plots their relationship to a third. Developed and designed by the Industrial Division essentially as a research tool, the new instrument, known as an Electronik Duplex Function Plotter, is said by the company to be especially useful in a wide range of industrial research activities from missile and engine testing to stress and nuclear engineering analysis. It is reported that in aerodynamic research, for example, the instrument could plot vibration amplitude and discharge pressure versus speed, or dynamic pressure and yaw angle versus immersion depth. . .A control system to permit aircraft to land automatically on aircraft carriers is being developed by the company in cooperation with the Bureau of Ships. Components for the system have already been built and installed in an airplane. The system is now being flight tested. . . A new midget chopper has been developed by the Aeronautical Division. This chopper is 75 per cent lighter and 70 per cent smaller than previous models. It weighs 2 oz. and measures $2^{1}/_{16}$ in. high by $^{15}/_{16}$ in. square. . .A booklet recently published by the company describes the full line of gyros built by the Aeronautical Division. It illustrates, describes, and gives complete specifications, variations, and potentiometer data on all rate (damped and undamped) vertical, cageable vertical, and floated gyros currently being manufactured. . .A new booklet entitled *Lightweight Fuel Gage Systems* has been put out by the Aeronautical Division.

• **Northrop Aircraft, Inc. . . .** A contract for extensive boundary-layer-control research

The first antisubmarine warfare helicopter, the HSL-1, has been delivered to the U.S. Navy by Bell Aircraft Corporation, according to a recent announcement. This tandem-rotor ship was flown from Hicks Field, Fort Worth, Tex. (where this picture was taken), to Eglin AFB, Fla., to undergo extensive tests at the Climatic Test Hangar located at Eglin. Bell Aircraft was awarded the antisubmarine helicopter development contract in June, 1950.

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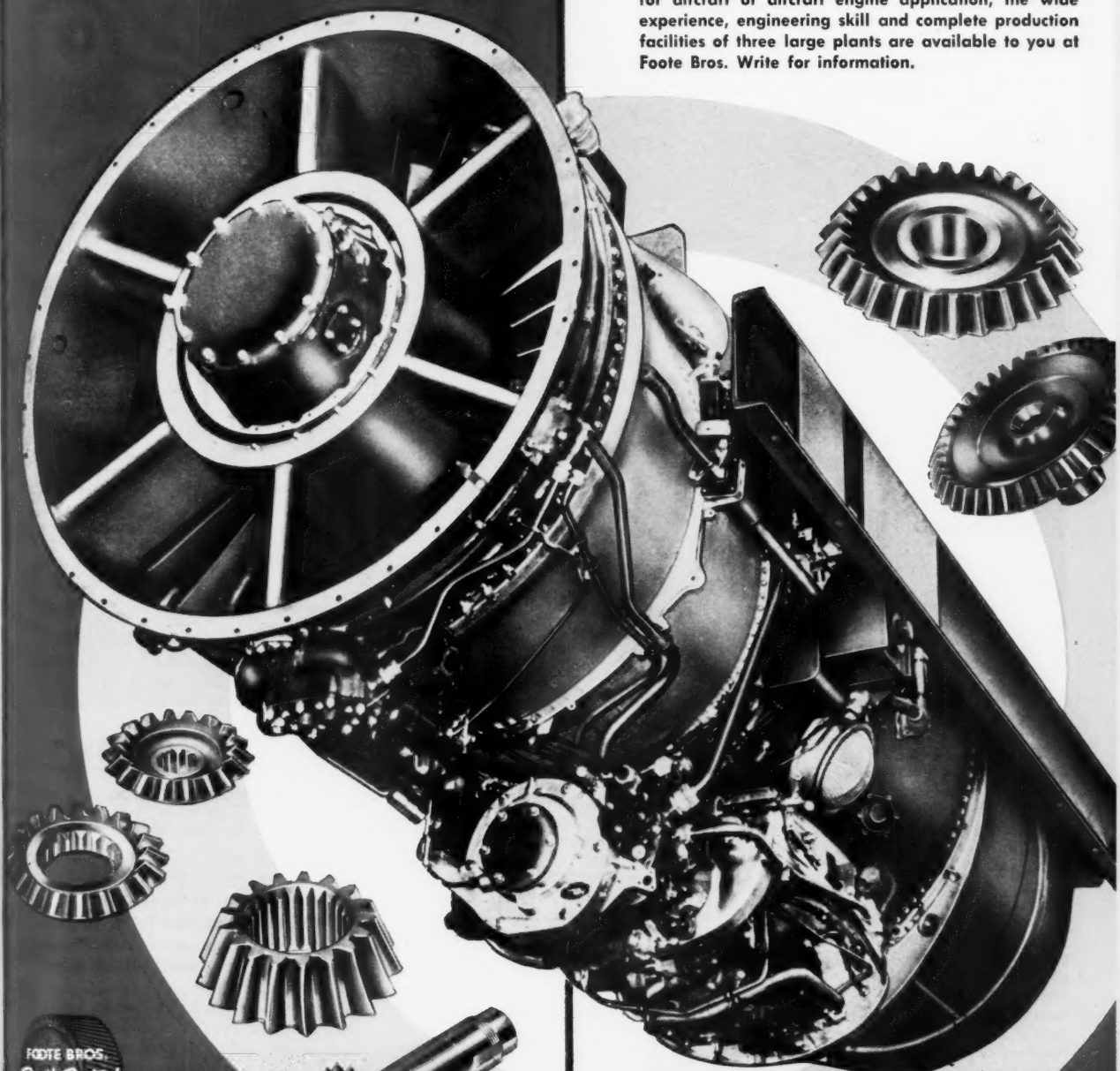

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A new two-place jet trainer was recently announced by Lockheed Aircraft Corporation. According to Lockheed engineers, this 600-m.p.h. aircraft features, among other things, a parabrake 'chute to slow the plane on landing, a raised rear seat to give the instructor better visibility and a closer watch on his student, speed and climb equal to many combat jets, and special wing devices to permit stalls in complete safety. Besides basic flight indoctrination, the trainer can be used for instruction in advanced navigation, gunnery, rocketry, dive bombing, and all-weather flight. The prototype is powered by a J33-A-16A turbojet engine, provided by Allison Division, General Motors Corporation. Approximate dimensions of the new plane are: length, 38 ft.; height, 13 ft.; and span (including 230-gal. tip tanks), 42 ft.

has been awarded to Northrop by the U.S. Air Force. Company engineers are investigating methods of improving the aerodynamic characteristics of airplane wings by experimenting with various devices designed to draw off part of the boundary layer. Personnel at Northrop have been conducting boundary-layer experiments for several years. . .A Weapons Systems Analysis Department was recently established at Northrop "to provide additional data to Engineering Management to assist in the new weapon systems development concept." Herbert K. Weiss, AFIAS, and Ward B. Dennis, MIAS, are Chief and Assistant Chief, respectively, of the new department. . .The buildings at Northrop's new production flight-testing facility at the USAF Jet Test Center, Palmdale, Calif., were completed early in February. Northrop's 250,000 sq.ft. facility will go into full operation upon the completion of the runways and other joint flight facilities, which will be about mid-1954. Northrop's portion of the USAF Jet Test Center encompasses 227 acres. . .An exclusive license has been awarded by Northrop to Standard Safety Equipment Company, of Chicago, for the manufacture and marketing of a Northrop-developed explosion suppression device for inerting empty fuel cells. This Chicago firm plans to manufacture the explosion suppression device under the trade name, "Inertor". . .An exclusive license to manufacture and market a Northrop-developed cable slack compensator has been awarded by Northrop to E. H. Stau Company, of Los Angeles. This cable slack compensator was designed by Northrop's electromechanical design group as a method of eliminating slack in aircraft control system cables. It is currently being used on the aileron and elevator control systems of the F-89 Scorpion.

• **The Parker Appliance Company. . .**W. H. Salisbury & Company, of 401 N. Morgan St., Chicago, Ill., is now a distributor of the Parker-manufactured synthetic rubber O-rings. Salisbury carries a stock of all popular sizes of standard service O-rings.

• **Piasecki Helicopter Corporation. . .**It was reported by the company that the YH-16 Transporter has reached a speed in excess of 100 m.p.h. (90 knots) in early forward flight tests. During these flight tests, the Transporter was carrying $1^1/_2$ tons of instruments and recording equipment. Take-off gross weight of this helicopter is more than 15 tons. . .The company's wholly owned subsidiary, Piasecki Helicopter Company of Canada, Ltd., has opened a maintenance base at the former RCAF airdrome in Arnprior, Canada, 43 miles west of Ottawa. RCAF H-21 Work Horse helicopters are to be overhauled, modified, and repaired at this facility. In addition, this Canadian facility is to manufacture simple types of replacement parts and overhaul tools, as well as jigs and fixtures. The RCAF was scheduled to take delivery on the first of its Piasecki H-21 Work Horses last month; these helicopters were purchased through the USAF. J. C. Charleson is the Manager of the Arnprior operation. . .The company is taking steps to reactivate its program to have the YH-21 Work Horse certificated for commercial sales. The company reports substantial interest in the Work Horse configuration from both air-line and industrial companies.

• **Pratt & Whitney Aircraft Division, United Aircraft Corporation. . .**With the conclusion of a Facilities Loan Agreement between Pacific Airmotive Corporation and United Aircraft and the subsequent installation of Government-owned test equipment at PAC's Burbank, Calif., plant, Pratt & Whitney jet engines can now be overhauled on the West Coast. This precludes the necessity of West Coast aircraft manufacturers sending Pratt & Whitney jet engines back to East Hartford, Conn., for overhaul. Pratt & Whitney had previously furnished PAC with the equipment necessary to disassemble and reassemble fuel control systems for the J-48 and J-57 engines.

• **Republic Aviation Corporation. . .**Important contractual agreements to implement the repair and overhaul of Republic F-84 Thunderjet fighter-bombers flown by the Royal Netherlands Air Force have been signed by Republic Aviation International, S.A., and the Dutch firm, Industriemaatschappij Avio-Diepen N.V. . . . H. C. Pillman was recently elected Assistant Secretary-Treasurer of the corporation. Succeeding Mr. Pillman in his former post of Controller is Paul F. Mason.

• **Vickers, Inc. . . .**A new 19-page illustrated booklet entitled *Servo Pump Units and Their Application in Hydraulic Transmissions* has been put out by Vickers. This brochure, Descriptive Summary SE-15, is available to qualified technicians who write to the Vickers' office in Detroit.

• **Weston Electrical Instrument Corporation. . .**Two appointments recently announced by the company are Frank X. Lamb as Vice-President and Roswell W. Gilbert, MIAS, as Assistant to the President. Mr. Lamb retains his former title of Chief Engineer and assumes the additional responsibilities in supervision of mechanical and electrical engineering activities. Mr. Gilbert, in addition to his new post, continues to serve as Director of Research.

IAS Sections

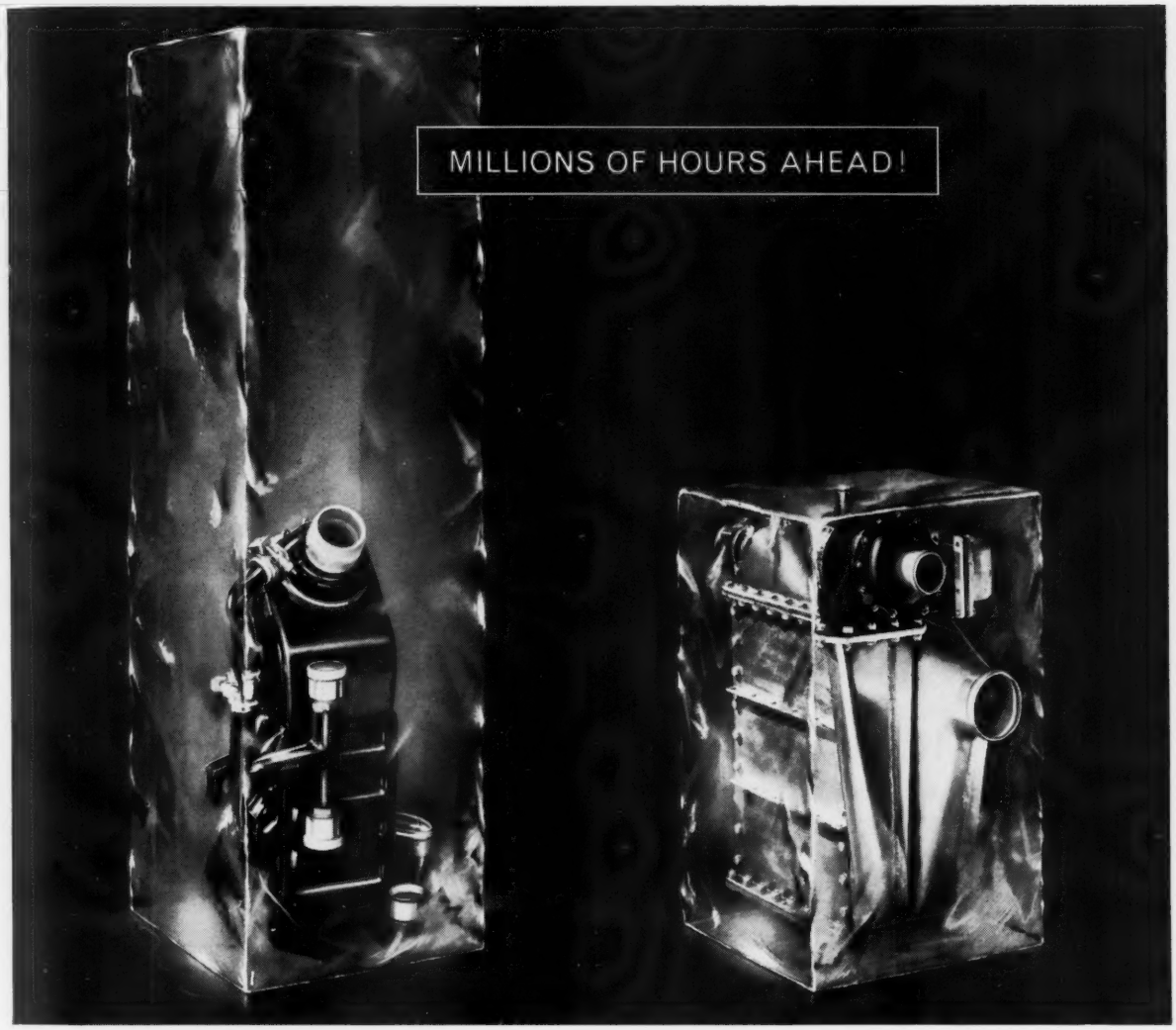
Baltimore Section

Richard W. Sanford, *Secretary*

The forty-seventh meeting of the Baltimore Section of the Institute of the Aeronautical Sciences was held in Maryland Hall at The Johns Hopkins University, on January 7 at 8:30 p.m. There were approximately 100 members and guests present.

The speaker was H. H. Porter, Assistant Director of the Applied Physics Laboratory of The Johns Hopkins University. He spoke on the subject of "Guided Missiles and Air Defense."

Mr. Porter opened his talk with a review and evaluation of the two classes of weapons that can be used in air defense, which he defined as prediction and nonprediction weapons. The prediction weapons consist of antiaircraft guns and rockets. These are fast losing their usefulness as the speed of planes increases, the range of weapon release



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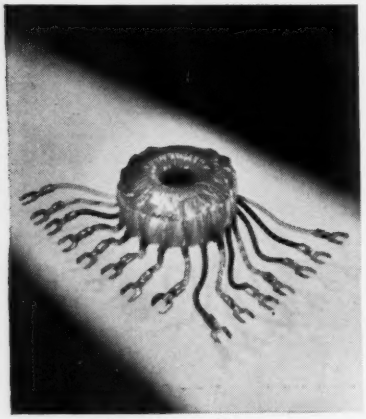

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lengthens, and the vulnerabilities of the targets decrease. The nonprediction weapons are the interceptors and guided missiles. Since these are controlled all the way, no prelaunch prediction is needed, and the inaccuracies of prediction systems are avoided.

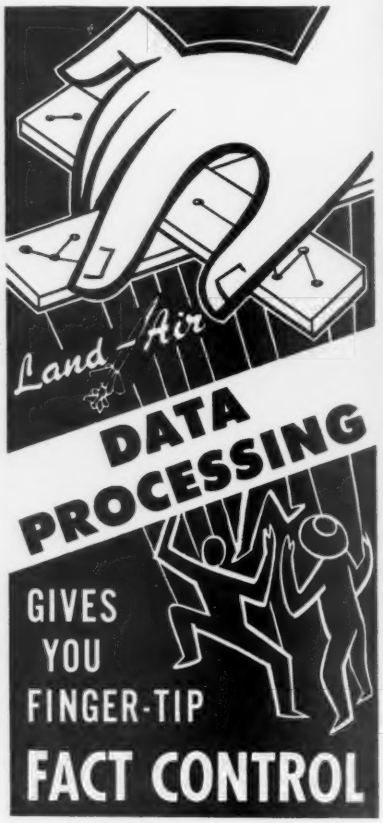
Mr. Porter then pointed out that, in principle, the only difference between an interceptor and a guided missile is the utilization of a pilot. The requirement for a pilot imposes cost problems of training, housing, etc. Furthermore, as speeds increase, the pilot's slow response is a considerable handicap. If the enemy attacks when visibility is limited, the pilot must receive his information through the same channels used by a guided missile, such as radar or ground command. The presence of the pilot dictates a minimum plane size, requires cooling for high-speed flight, and limits the accelerations that can be made. Considerations of pilot safety also increase the cost of the planes and control systems. The presence of the pilot makes an additional weapons system necessary so that he can destroy the target from a distance sufficient to reduce the effects of the bomber's defense.

The biggest advantage of the piloted interceptor is that it already exists as a proved weapon in service. Mr. Porter pointed out that this advantage must not be taken lightly and that the existing weapons system cannot be replaced by "paper" weapons. On the other hand, if the existing weapons system cannot meet the requirements for adequate air defense without enormous improvement, these weapons systems and their improvements are also basically "paper" weapons.

The primary requirements of a guided missile are accuracy, lethality, and range. Other requirements are reliability and economy for the results produced. Fortunately, great strides have been made in the necessary technical fields, and it is possible to foresee and develop the techniques for effective missiles.

Mr. Porter then went on to consider the ground-based system required by each weapon. Guided missiles need tracking radar and computers, storage and maintenance facilities, handling equipment, and launchers. Each installation must have trained crews and all the logistic requirements to support them. Interceptors require airfields, including hangars and maintenance facilities, trained crews, and logistic support. They need GCI centers to guide the planes to their targets and to direct them to landing fields.

In addition, there must be early warning, analysis of the attack, command decision, and the orders to the weapons installations. In order to realize the



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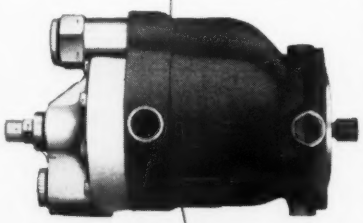

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scope of the defense that would be required against a future air attack, Mr. Porter presented a simplified version of a hypothetical attack against Washington, D.C., by 600-m.p.h. bombers and a possible defense by guided missiles of twice this velocity with a range of 50 miles and by high-performance interceptors. In a reasonably successful defense, the enemy attack would have to be detected over Boston; the interceptor's base would have to be alerted when the enemy reached Hartford, Conn., with first contact by the interceptors with the enemy over Newark, N.J. The guided-missile site would be alerted as the attackers reached Trenton, N.J., and the first missiles would be launched as the enemy approached Wilmington, Del. The first enemy planes that could be shot down by the guided missiles would be near Elkton, Md.

Although this scope of action appears large, the problem is much more complex than was illustrated. An attack may consist of many planes, and to counter, it would require hundreds of interceptors and guided missiles in the air. The problem of keeping track of all enemy planes and coordinating our weapons into an effective defense is staggering, particularly when it must be realized that the enemy will try to saturate and confuse the defenses by concentrating several attacks, by feinting at targets and then attacking others, or by splitting up to attack several targets simultaneously in an attempt to draw the defenses out of position or to force them to reduce their resources before the main attack arrives.

The picture of defense envisaged three stages: first is the distant early warning—this should give about 5 hours notice to alert the defense properly; the second is the perimeter early warning radar, whose function is to delineate the attacks so that the alerted and proper defense weapons can go into action; and third, beyond these must be a coverage of radar and weapons installations, thickly spread to protect our valuable targets and thinly spread over less important areas. It is obvious that the initial cost and upkeep of such a complete defense system is enormous.

Mr. Porter pointed out that the scale of defense required is not really clear. Wars are won by the use of offensive power to destroy the enemy's forces. Therefore, against an enemy of equal power, the basic principle must be to provide the greatest offensive power we can. We must select our scale of defense so that it is not so large as to divert too much from our primary effort—i.e., the attack—nor so little that the enemy can seriously impair that effort.

Mr. Porter then briefly analyzed the relative situations of our only dangerous potential enemy and ourselves. He pointed out that, technologically, Russia is far behind the United States. Moreover, the Russian population is tired and not basically loyal to the government in power. Control has been maintained only by a police state organization in which millions of people have been sent to slave labor or concentration camps. Russia has milked her satellite states since seizing control. The uprisings in Poland, Czechoslovakia, and East Germany show their hostility. Beyond these doubtful allies of Russia exists a world made hostile by Russia's avowed aim of world communist domination. These countries are industrially far more advanced than Russia. They support military bases within striking distance of Russia's important areas. Beyond these countries and practically out of reach is the United States, whose industrial potential has out-supplied the rest of the world in two major wars.

On the other hand, consider the position of the United States. We have far greater production capabilities and enormous output per man-hour of effort. We have a loyal population. We have allies all over the world. We have advance bases around our potential enemy.

For years we have been looking at Russia's possible strength. Mr. Porter did not believe we have fully assessed Russia's weakness. He demonstrated that a realistic estimate of the enemy capabilities and intentions, as well as our situation and needs, is a prime requisite in determining the defense strength we should provide. He concluded that, on the basis of information available to him, an adequate defense is attainable.

At the conclusion of his talk, which was well illustrated with slides and examples, Mr. Porter showed a film of several test vehicles in flight. These included a modern motion-picture sequence of the earth as obtained from a V-2 rocket. After a question-and-answer period, the meeting was adjourned.

Chicago Section

Leland W. Sims, *Secretary*

On January 20, the Chicago Section was a guest of the Ford Motor Company's Aircraft Engine Division for dinner and a tour of the plant. At 6:30 p.m., dinner was served in the executive dining room to 89 members and guests who unanimously described it as a "wonderful meal." After dinner and prior to the tour, which started at 7:45 p.m., Chairman Alfred F. Stott opened a short meeting, at which time he expressed thanks to the Ford Motor Company and to A. C. Moore, General Manager, and Ralph N. DuBois, Chief Product Engineer, for making the tour possible. Mr. Stott then introduced B. D. Mills, Assistant Manager, who heartily welcomed all to the plant and described the manner in which the tour was to be conducted.

The group was then divided into two sections. One section took the tour, which lasted 55 min., while the other section was given a lecture and shown two films. This was repeated when the sections changed places.

The tour was conducted by four members of the Training Department: E. H. Attwood, W. D. Howard, J. Collins, and J. F. Picraux. Four novel and comfortable powered vehicles were provided to transport the guests around the plant, which covers over 80 acres. Each vehicle consisted of three flat cars pulled by a tractor. Each vehicle was manned by a driver and a member of the Training Department who spoke through a P.A. system mounted on the vehicle. The areas of the plant which were shown were the unrestricted parts of the production facilities of the R-4360 reciprocating engine (three models) and some of the component parts manufactured for the J-57 jet engine.

During this time, the other section was given a lecture by James Moriarity, of the Training Department. He described, showing charts, the significant parts of the three models of the R-4360 engine. He also illustrated, with a rotating peg board, a typical flow system for production of an engine. Two films were shown: General Electric's *Jet Story* and *Effects of Foreign Matter on Jet Engines.*

The tours and lectures were concluded at 10:00 p.m.

Los Angeles Section

Evert C. Hokanson, *Secretary*

The first 1954 dinner meeting of the Los Angeles Section established a standard that will be most difficult to meet during the remainder of the year. On the evening of January 21, Jerome F. McBrearty, Chief Structures Engineer for Lockheed Aircraft Corporation, gave the first U.S. presentation of the timely paper "Structures for High Speed Aircraft," authored by the speaker and Hall L. Hibbard, Lockheed's Vice-President—Engineering. Mr. Hibbard originally presented the paper at the Fourth Joint International Aeronautical Conference of the Royal Aeronautical Society and the Institute of the Aeronautical Sciences in London, England.

Mr. McBrearty, speaking with ease and fluency interspersed with excellent humor, made his presentation the most enlightening and interesting structures paper the writer has had the pleasure of hearing. The speaker covered the

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major problems facing aircraft structural engineers in the foreseeable future and the tools available for solving these problems. The paper was divided into three major phases—(1) structural problems, (2) methods, and (3) materials. Each phase was amply illustrated with colored slides and charts.

Because 22 to 46 per cent of the aircraft is structure, it is a fertile field for investigation. New methods and materials must be developed because of the temperatures resulting from high-speed operation. Military aircraft encounter another temperature problem that must be considered. This is the effect of heat from atomic bombs.

The methods for solving the multitudinous problems has outgrown the slide rule, which can average 40 computations per hour. To correct this deficiency, modern methods must be used, such as the IBM calculator which can produce 1,900 calculations per hour. A new method has been successfully developed for high-speed model testing by the use of rockets. For many tests, this method, in which the sky replaces the wind tunnel, is far superior and less expensive.

Of course, the value of increased use of telanium alloys was stressed, but greater advances in material developments are on the horizon. It may well be that new knowledge of atomic bonding strength will be the key to the storehouse of the stress-analysis dream material.

Prepared comments were given by C. H. Stevenson, Chief of Strength and Weights, Douglas Aircraft Company, Inc., El Segundo Division, and George N. Mangurian, Chief of Structures, Northrop Aircraft, Inc. Mr. Stevenson pointed out that, while speeds had increased tenfold, the structural loads had increased 100 times during the past few years. Mr. Mangurian proposed that the reduction in safety factors, made possible by increased knowledge, would pay the greatest dividends in the near future.

Section Chairman, Richard R. Heppe, presided over the meeting. He introduced the speaker and the new chairmen of the various Section committees. The student guest for this meeting was Edward Lundby, Chairman of the Cal-Aero Technical Institute Branch. Mr. Heppe announced that plans for the Annual Summer Meeting were well under way and requested that anyone who had a paper on an outstanding subject for that meeting should present it promptly to the Summer Meeting Committee. An enthusiastic audience of over 350 attended the meeting.

▶ Norman L. Fox, Aerodynamics Group, Douglas Aircraft Company, Inc., Santa Monica Division, presented a paper and movie on "The Effect of Aircraft Jet Engine Exhaust Impinging on Airfield Surfaces" at the January 14 Specialist Meeting. He presented data that showed that, for a stationary jet, the runway surface temperature reached the temperature of the incident jet blast within 15 min. It has also been proved that scale-model tests could be used for further tests and that the results are applicable to full-scale operations. Considerable discussion followed the paper by representatives from the concrete industry, as well as the aviation industry.

Shown at the head table during the January 13 meeting of the St. Louis Section are, *left to right:* P. R. Des Jardins, Section Treasurer and with the Army Aviation Field Service; W. Cederlund, CAA; J. H. Meyer, Section Chairman and with McDonnell Aircraft Corporation; G. Merritt Preston, speaker of the evening and with NACA's Lewis Flight Propulsion Laboratory; C. J. Wenzinger, Section Advisory Board member and with Sverdrup and Parcel, Inc.; L. K. Edwards, Section Program Chairman and with McDonnell Aircraft Corporation; and G. S. Graff, Section Secretary and with McDonnell Aircraft Corporation.

St. Louis Section

George S. Graff, *Secretary*

The first meeting of the St. Louis Section to be held in 1954 took place at the Melbourne Hotel on January 13. The highly successful social hour and dinner before the meeting were attended by more than 80 members and guests.

Introduced by Chairman John Meyer, G. Merritt Preston, speaker for the evening, talked about the crash fire phase of the NACA's Flight Safety Program. Mr. Preston is Chief of the Flight Research Branch, Lewis Flight Propulsion Laboratory, NACA.

The theme of Mr. Preston's talk, which was spectacularly highlighted by a colored movie of fires following simulated crash landings, was that one cause of fire following a crash is a fuel mist that forms upon rupture of the airplane's fuel cells. This fuel mist and the causes of its formation and propagation were among the more important discoveries made during the NACA crash-fire investigation.

Mr. Preston pointed out that, although the burning of the fuel mist itself is seldom hazardous, since it is rapid, it does provide ignition for the liquid fuel. Thus it is a most important link in the chain of events leading to a serious crash fire.

During the subsequent discussion of causes of ignition of the fuel mist, the speaker took occasion to indicate that a pilot should not cut his ignition when a crash is inevitable until after the fuel flow to the engine has been stopped. When the ignition is cut, he maintained, the raw gas mixture merely travels unburned through the engine and ignites in the hot exhaust manifold, thus providing an excellent ignition source for the fuel mist. The best procedure, he declared, is to cut off the fuel to the engine and inert the inside of the engine and manifolds, and then to cut the ignition. Another, and least suspected source of ignition, he concluded, is electrostatic discharge from the crash fragments; this phenomenon accounted for one of the 17 crash fires observed during the NACA investigation.

The formal talk was followed by a question - and - answer period, during which Mr. Preston pointed out that the 17 crashes constituting the program of investigation represented, in reality, only three particular types of crashes. He cautioned those present against applying conclusions drawn from this program to any other type of crashes.

San Diego Section

H. C. Matteson, *Corresponding Secretary*

Classical flutter and its investigation was the subject for a technical meeting held on January 12. The speaker was Michael Dublin, Chief of Dynamics, Convair, San Diego.

Mr. Dublin presented a broad view of his subject, ranging from the mathematical theory to flight-test procedures and means of prevention of flutter. He described the flutter mechanism, discussed response curves and their significance, and reviewed the techniques employed in the evaluation of the flutter characteristics of aircraft. Flutter model test techniques were also discussed. Mr. Dublin augmented his talk with slides and graphically illustrated the significance of flutter by presenting a movie showing wind-tunnel investigations of various flutter models on a modern high-speed airplane.

Mr. Dublin's talk was highly appreciated by an audience of 75. Following a customary practice, coffee and dough-

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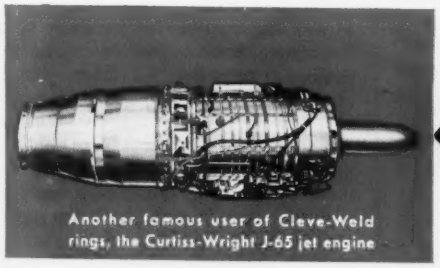

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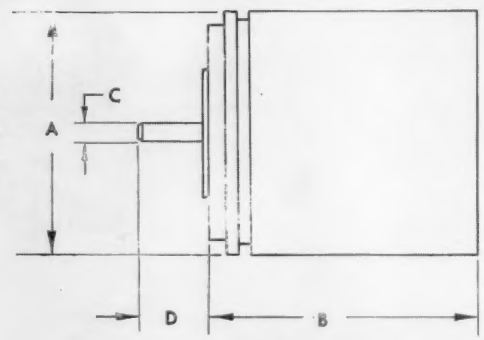
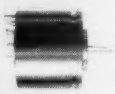
15 Teeth 96 Pitch .1771" O.D.

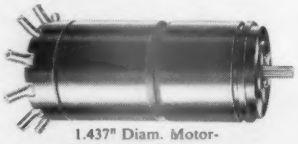
D Plain Shafts from 5/16" to 1/2" long
Pinion Shafts from 5/32" to 7/16" long



R-110, 111, 112 Servo Motor

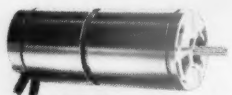


.938" Diam. Servo Motor



1.437" Diam. Motor-Tachometer Generator

1 1/16" Diam. Geared Servomotor



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nuts were served at the close of the formal meeting.

▶The San Diego Section held its first dinner meeting of the new year on January 29. The speaker for this occasion was Arthur E. Raymond, whose talk was entitled "Twenty Questions." Mr. Raymond is Vice-President in Charge of Engineering, Douglas Aircraft Company, Inc., and is a Past-President and Honorary Fellow in the IAS. He effectively employed his broad background of experience in the aircraft engineering field to discuss many of the more controversial points of view regarding the design of modern high-speed aircraft.

At the outset, Mr. Raymond pointed out that aircraft design is a matter of compromise. He illustrated this point by discussing the various factors involved in the selections of the wing configuration for a high-speed aircraft. It was emphasized that no single planform arrangement can be considered optimum regardless of other factors. He noted that one complicating factor in this matter is that the aerodynamic "folk-lore" is sometimes doubtful.

Mr. Raymond reviewed many of the more confounding problems associated with the selection of the optimum power plant and its location. He elaborated on this subject by considering the case for a high-speed civil transport. Aerodynamic and structural efficiency are but two of the factors involved. In addition, the noise problem, maintenance factors, safety, cost, and engine availability are equally important. The noise problem in and around civil airports may well be the most significant factor with regard to the type of power plants selected for future civil transport aircraft.

Mr. Raymond closed his talk with some thoughtful remarks on aircraft design philosophy, amusingly illustrated by personal experience. A question-and-answer period followed. The audience of 175 members and their guests thoroughly enjoyed Mr. Raymond's considered appraisal of some of the more perplexing problems facing today's aircraft-design groups.

Seattle Section

Russell B. Light, *Secretary*

In honor of the fiftieth anniversary of the Wright Brothers historic first flight, the Seattle Section had as its speaker at the December 17 meeting a Boeing Airplane Company pioneer, Fred P. Laudan, Vice-President—Manufacturing.

Mr. Laudan has seen every Boeing airplane in production except the original "B & W" which was built while he was completing engineering studies at the University of Washington. Born in Paola, Kan., in 1894, Mr. Laudan

joined Boeing as a Draftsman in 1919. He became Project Engineer in 1922 and had much to do with making possible mass production. He became Factory Superintendent in 1928 and 10 years later was named Vice-President. Since that time, his title has varied—Vice-President and Superintendent of the Seattle plants; Vice-President and Manager of the Renton Division (during World War II); Vice-President—Experimental Manufacturing; and finally, Vice-President—Manufacturing. He directed all factory work on the Stratocruiser, as well as experimental and production activities of Boeing's B-50, C-97, XB-47, and B-52, and now has all Boeing factory operations in Seattle under his supervision.

The speaker was introduced by the Seattle Section Chairman, "Nick" Ledbetter, who gave an interesting résumé of the first 50 years of flight.

Mr. Laudan confined his remarks to Boeing's contribution to flight during its 37 years of existence. His talk, both informative and entertaining, was illustrated with slides showing the genealogy of Boeing types, starting with the "B & W" (Boeing & Westervelt) and ending with the B-52 and "Project X."

Mr. Laudan closed his talk with the following, which, while directed primarily to Boeing people, could well apply to the entire aviation industry: "Much has been accomplished by Boeing men in the past 37 years, and, if we develop those working for us and with us and pass on our engineering and manufacturing knowledge and know-how to others so that they can assume responsibility and carry on, nothing within the realm of our fondest dreams will be impossible."

The presence of many of Boeing's "30-Year Club" members as guests of the Seattle Section gave added interest to the meeting, for Mr. Laudan told many stories about these pioneers.

▸ The January 14 meeting was held in Guggenheim Hall on the University of Washington campus where approximately 200 members and guests assembled to hear a talk by A. Scott Crossfield, NACA Research Test Pilot. The subject of the talk was "The NACA High Speed Research Program."

Mr. Crossfield served as a fighter pilot with the Navy during World War II and was active in the Naval Reserve program after the war. He attended the University of Washington where he earned his Master of Science degree in Aeronautical Engineering. Upon graduation, he was hired by the NACA and has been stationed at Edwards AFB, Calif., where he has been engaged in the high-speed research program.

Mr. Crossfield, who has flown all of the NACA high-speed research aircraft, pointed out that the NACA is not in the business of breaking records and that it was during a regularly scheduled flight test that he became the first man to fly at twice the speed of sound. In as much detail as security allowed, he discussed the field of investigation covered by each of the research aircraft. He stressed the importance of the research program as an aid in interpreting high-speed wind-tunnel data. A typical flight test was described starting with its inception and ending with the reduction of the data. The amount of planning and detail work for just a few minutes of flight was indeed impressive.

During the question period after the regular meeting, Mr. Crossfield was asked to comment on the pilotless type of aircraft; he stated that "the guided missile undoubtedly had its place, but it was self-evident that the pilot was still the only servomechanism that could be produced in large quantities with unskilled and low-paid labor."

Through the courtesy of the NACA, an interesting color film showing most of the research planes in flight was shown.

Wichita Section

Charles V. Petrie, *Secretary*

The December dinner meeting celebrated the Fiftieth Anniversary of Powered Flight and was a joint meeting with the local chapter of the Society of Automotive Engineers. The meeting and social hour were held at the Broadview Hotel. Wives of IAS and SAE members were guests.

Phil McKnight, Public Relations Director for Beech Aircraft Corporation, acted as toastmaster and honored the following pioneer and present-day aviation leaders: Sam Bloomfield, President, Swallow Airplane Company; Max Walton, associated with Swallow Airplane Company during its formative years; Marcellus M. Murdock, Publisher of the *Wichita Eagle* and Chairman of the first Aviation Committee of the Wichita Chamber of Commerce; Milford Vanik, Chief of Technical Staff, Boeing Airplane Company, Wichita Division; Jack Gaty, Vice-President and General Manager, Beech Aircraft; Tom Salter, Chief Engineer for The Cessna Aircraft Company; A. S. Swenson, former Aviation Representative for the Wichita Chamber of Commerce; Bill Pearce, Chairman of the Wichita IAS Chapter; and Walter Roesing, Vice-Chairman of the Wichita SAE Chapter.

The speaker of the evening was Victor E. Moore, Assistant Director of Air World Education for Trans World Airlines, Inc., who spoke on "The Fiftieth Anniversary of Powered Flight and Trends for the Future."

Mr. Moore pointed out that aviation is the most dynamic thing that man has ever created because it has broken down all natural barriers between nations, such as oceans and mountains. The airplane has made us all neighbor nations. The only barrier left is a social barrier—lack of understanding. He suggested that we Americans begin teaching our children foreign languages in our schools, even at the kindergarten level, and that we send more people abroad, not to criticize but to learn to appreciate people of other nations as they are and become better acquainted with their cultures. He indicated that these peoples must be understood if we are going to keep the United States as it is and keep other parts of the world as our friends and markets.

Mr. Moore told of experiments he conducted in South America during which small children were easily taught several languages simultaneously. He also told of conversations with dynamic young German engineering students who speak several languages and state frankly that they expect to be the leaders of a United States of Europe. He also pointed out that the people of the United States tell our statesmen what to do, but we do not have enough knowledge of world affairs.

His talk reviewed the past 50 years of flight and parallel developments in other fields. He predicted that we would have space travel and a satellite station within the next 50 years.

Mr. Moore concluded with the thought that the youth of today will accept the world we give them and that how well they lead the world will be determined by the kind of guidance and training we give them.

Members Elected

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the REVIEW.

Elected to Associate Fellow Grade

Nunez, Antonio, Ing., Dir.-Gen. "Esteban Terradas" National Institute of Aero. Technology (Madrid).

Elected to MEMBER Grade

Bowden, Roger G., M.Sc. in Theoretical & Applied Mechanics, Devel. Engr., Flight Analysis Group, Autopilot Section, Aero. Div., Minneapolis-Honeywell Regulator Co.

Curry, Herman H., B.S. in E.E. & M.E., Drawing Checker, Lockheed Aircraft Corp.

Daggett, Max, Jr., B.S.Ae.E., Engrg. Designer "B," Temco Aircraft Corp.

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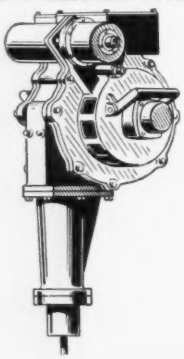

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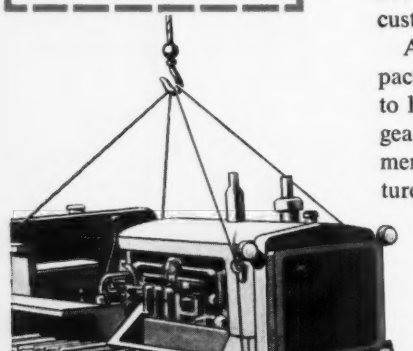

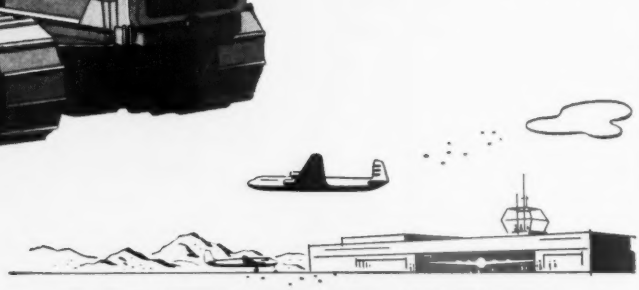

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Hayes, Wallace D., Ph.D., Scientific Liaison Officer, Office of Naval Research (London).

Landis, Fred, Sc.D., Asst. Prof., Mech. Engrg., New York University.

Love, Eugene S., B. of Ae.E., Head, 9-Inch Supersonic Tunnel Section, NACA, Langley AFB.

Mantz, Paul, Pres.-Owner, Paul Mantz Air Services.

Martin, Rowland E., Chief Test Pilot In Charge of Flight Test, Aeroproducts Operations, Allison Div., General Motors Corp.

Notscheff, Iwan, Engr. "B," Canadair, Ltd.

Pion, Noel W., Design Engr., Propulsion Div., North American Aviation, Inc.

Proctor, Kent, B.Sc.M.E., Research Engr., Northrop Aircraft, Inc.

Stevenson, Nevin J., Jr., M.S.Ae.E., Lt. Comdr. & Asst. for Aircraft Material, Cinclantflt Staff, USN (Norfolk).

Stroud, John F., B.Sc.M.E., Thermodynamicist "A," Lockheed Aircraft Corp.

Transferred to MEMBER Grade

Faget, Maxime A., B.S.M.E., Head, Propulsion Aerodynamics Branch, Langley Aero. Lab., NACA.

Ferguson, Charles W., B.S.Ae.E., Stress Analyst, Douglas Aircraft Co., Inc. (Santa Monica).

Johnson, Douglas H., B.A.E., Designer "B," Northrop Aircraft, Inc.

Low, George M., M. of Ae.E., Aero. Research Scientist, Lewis Flight Propulsion Lab., NACA (Cleveland).

Mooradian, Albert H., Lead Designer, Chance Vought Aircraft, Inc. (Boston).

Pittman, Walter D., B. of Ae.E., Struct. Group Leader, McDonnell Aircraft Corp.

Robinson, John O., M.Sc.Ae.E., Research Engr., Guided Missiles, Douglas Aircraft Co., Inc. (Santa Monica).

Steffens, Jerome, M.Sc. in Ae.E., Struct. Group Engr., Kaiser Metal Products, Inc.

Zemlin, Jerry P., M.S. in Ae.E., Devel. Engr.-Group Leader, Marquardt Aircraft Co.

Elected to Associate Member Grade

Austin, Homer M., Sales Engr., Hydro Aire, Inc.

Fenninger, Charles R., Contracting Engr., Consolidated Western Steel Div., U.S. Steel Corp.

Jones, Edward D., Component Inspector, A. V. Roe Canada, Ltd.

Mansfield, Dale E., Asst. Supvr.—Proof Planning, Consolidated Vultee Aircraft Corp. (San Diego).

Ritchey, Randolph, B.S.E., Mgr., Contractors Equip. Div., Consolidated Western Steel Div., U.S. Steel.

Rogers, Scott A., Jr., A.B., Mgr., Engine Accessories Div., The Parker Appliance Co.

Elected to Technical Member Grade

Abrams, Robert H., B.S., Jr. Engr.—Weights, North American Aviation, Inc.

Blumenfeld, Bert, B.S. in M.E. & Meteorology, Operations Engr., Field Engrg. Div., Wright Aero. Div., Curtiss-Wright Corp.

Bolon, Leslie Wilson, B.S.C.E., Equip. Engr., Lockheed Aircraft Corp. (Georgia Div.).

Martin, John F., Chief of Aerodynamics, Canadian Aviation Electronics.

Painter, Ethan A., Lt., R&D Group, Aircraft Div., Systems Coordination Br., Bureau of Aeronautics, USN.

Teng, Lee C., Ph.D., Asst. Prof., Physics Dept., Univ. of Wichita.

Vaughen, Jack F., B.S.Ae.E., Aerodynamicist, Helicopter Div., Bell Aircraft Corp.

Watkins, Thomas B., B.S.M.E., Aero. Research Scientist, Transonic & Supersonic Compressor Div., Lewis Flight Propulsion Lab., NACA.

Zienkiewicz, H. K., D.C.Ae., Aerodynamicist, Navigational Proj. Div., The English Electric Co., Ltd.

Transferred to Technical Member Grade

Chuck, Gilbert S. B., Research Engr., M.I.T.

Givler, Edwin G., Sr. Detailer, Hydraulic Design Group, Buick-Oldsmobile-Pontiac Assembly Div., General Motors Corp.

Haberman, Wolf, S.B. in Ae.E., 2nd Lt., USAF; Student Pilot, Bartow Air Base.

Jaksina, Stanley C., B.S., 2nd Lt., USMC; Platoon Comdr., 3rd Mar. Div., FMF.

Johnson, Robert R., Assoc. in Ae.E., Engrg. Draftsman, North American Aviation, Inc. (Columbus).

Nawrocki, H. Franz, B.S. in Ae.E., Jr. Engr., Marquardt Aircraft Co.

Perkins, Don, B.S. in Ae.E., Grad. Student-Sales Engrg., Westinghouse Electric Corp.

Prigge, John S., Jr., B.S. in Ae.E., Asst. Proj. Leader, D.I.C. Staff, Aero. Dept.-Aero-Elastics & Struct. Research, M.I.T.

Stevens, Joseph W., S.B. in Ae.E., Jr. Aerodynamicist, Chance Vought Aircraft, Inc.

Stough, Robert A., B.S.M.E. (Aero.), Jr. Design Engr., Industrial Products Div., Westinghouse Air Brake Co.

Stuchlak, Michael, Lab. Technician, The Garrett Corp.

Swan, Frederic F., B.S., Maj., USAF; Chief, Production Br., Hq., San Bernardino Air Material Area (Norton Air Force Base).

Taillon, Norman V.

Tangeman, Dale D., B.S., Jr. Engr. "B," Proj. Design Group, Boeing Airplane Co. (Seattle).

Tolosko, Raymond J., B.S.Aero., Lt., Pilot Training, USAF (Columbus Air Force Base).

Vaughn, Melvin L., Weight Analyst "A," Northrop Aircraft, Inc.

Velz, George T., B.S., Liaison Engr., Kaman Aircraft Corp.

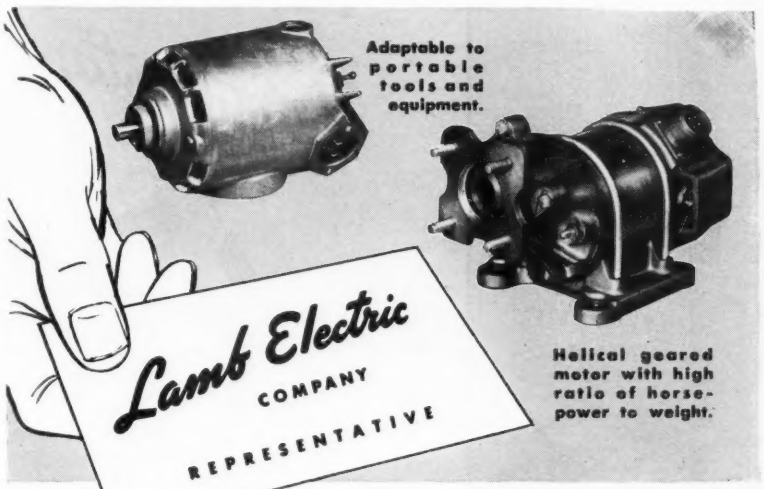
Verlangieri, Vincent C., S.B., Jr. Engr.-Loads Analysis, North American Aviation, Inc. (Downey).

Whitesell, William J., B.S., 2nd Lt., USAF; Student-Grad. Armament Systems, USAF Inst. of Tech., Wright-Patterson AFB.

Willis, Willis E., B.S., Test Engr., Continental Aviation & Engrg. Corp.

Wolf, Alfred A., Jr., B.S. in Ae.E., Aero. Engr., Sikorsky Aircraft Div., United Aircraft Corp.

Zove, Philip, B. of Ae.E., 2nd Lt., USAFR; Research Asst. (part-time), New York University.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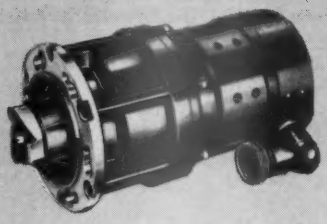

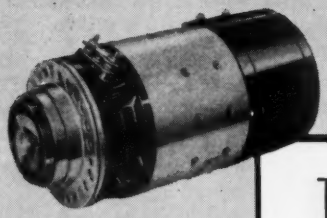

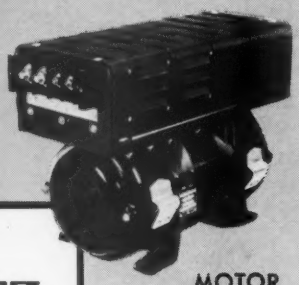

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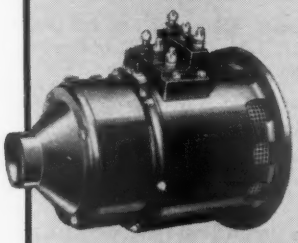

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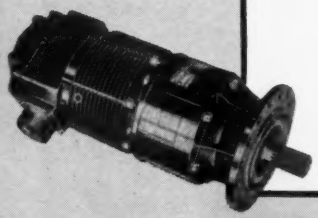

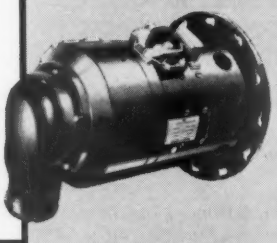

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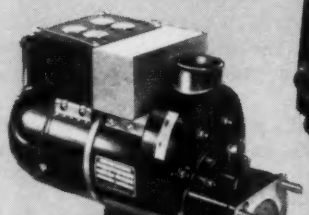

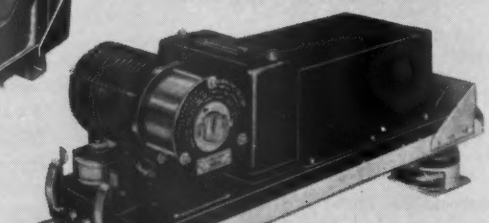

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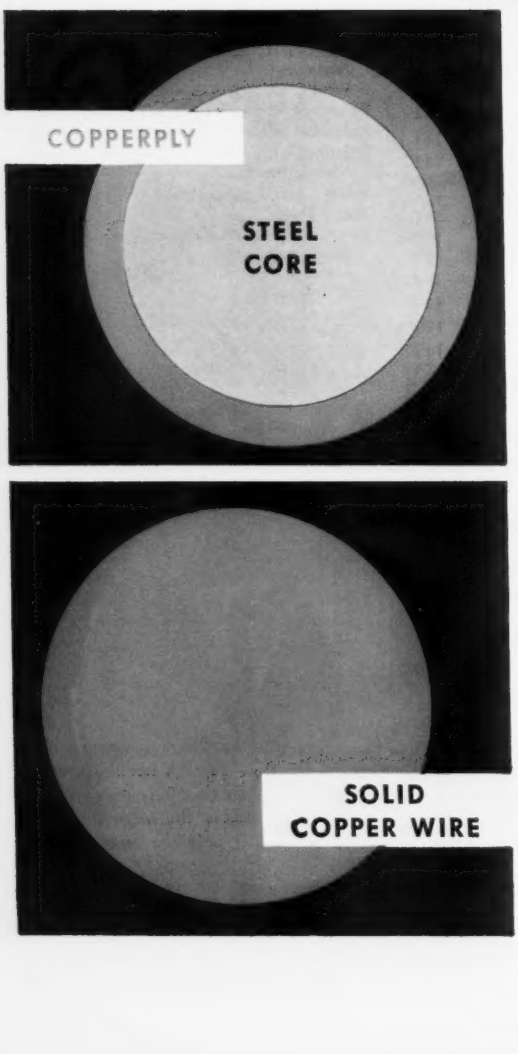

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Metal Decorating Equipment

Worcester Wire Works, Worcester, Mass.
Round and Shaped Steel Wire, Small Sizes

Aerodynamics

Investigation of Mutual Interference Effects of Several Vertical-Tail-Fuselage Configurations in Sideslip. William H. Michael, Jr. *U.S., NACA TN 3135*, Jan., 1954. 35 pp.

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Effect of Surface Roughness Over the Downstream Region of a 23° Conical Diffuser. Jerome Persh and Bruce M. Bailey. *U.S., NACA TN 3066*, Jan., 1954. 57 pp.

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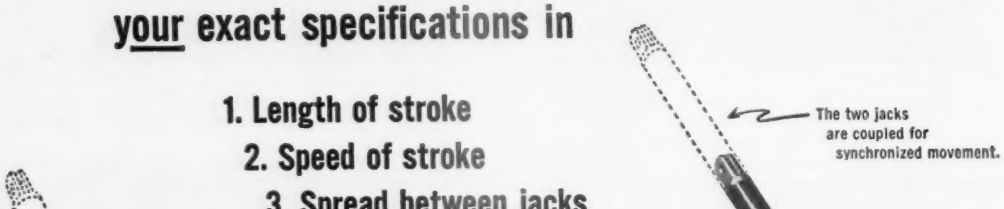

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a 23° Conical Diffuser at Subsonic Mach Numbers. Jerome Persh and Bruce M. Bailey. *U.S., NACA TN 3123*, Jan., 1954. 36 pp.

An Interferometric Study of the Boundary Layer on a Turbine Nozzle Blade. C. R. Faulders. *Trans. ASME*, Jan., 1954, p. 61.

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The Importance of Crosswind Forces Attainable from Moving Systems. Fred S. Eastman. *Trend in Eng.*, Jan., 1954, p. 10. Analysis includes limits of attainable lift and thrust at different ratios and the influence of crosswind velocity on lift, drag, and thrust.

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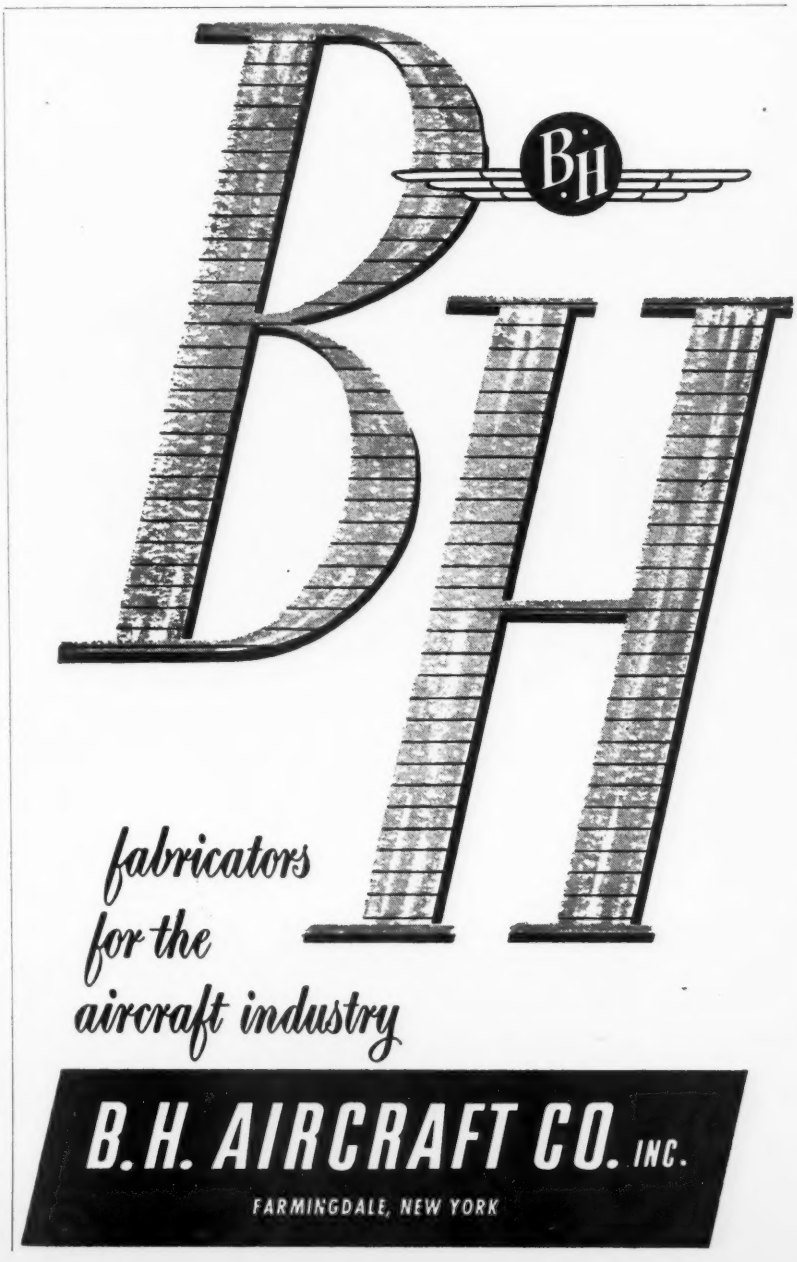

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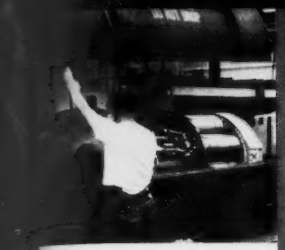
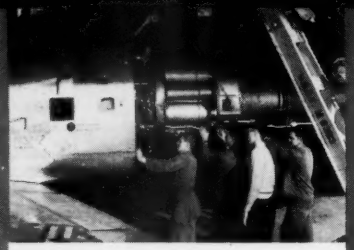


ON THE CANNING LINE. Technicians watch for engine mishandling, check packing procedures.



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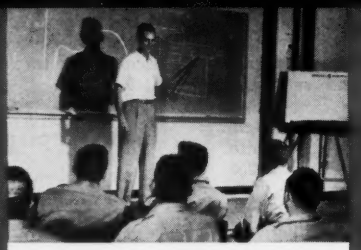

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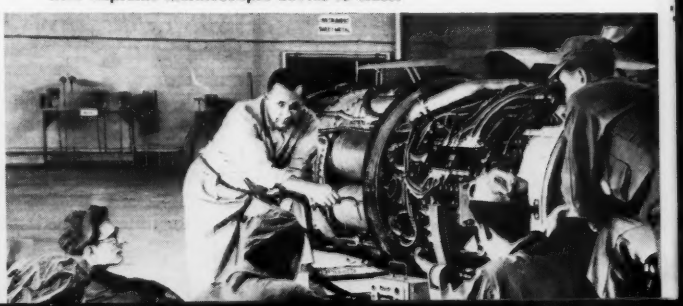

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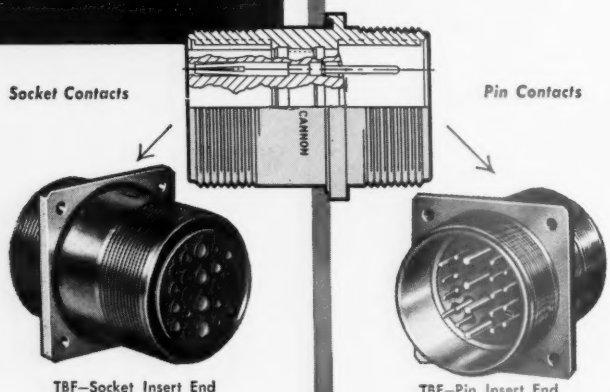

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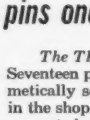

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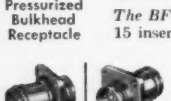

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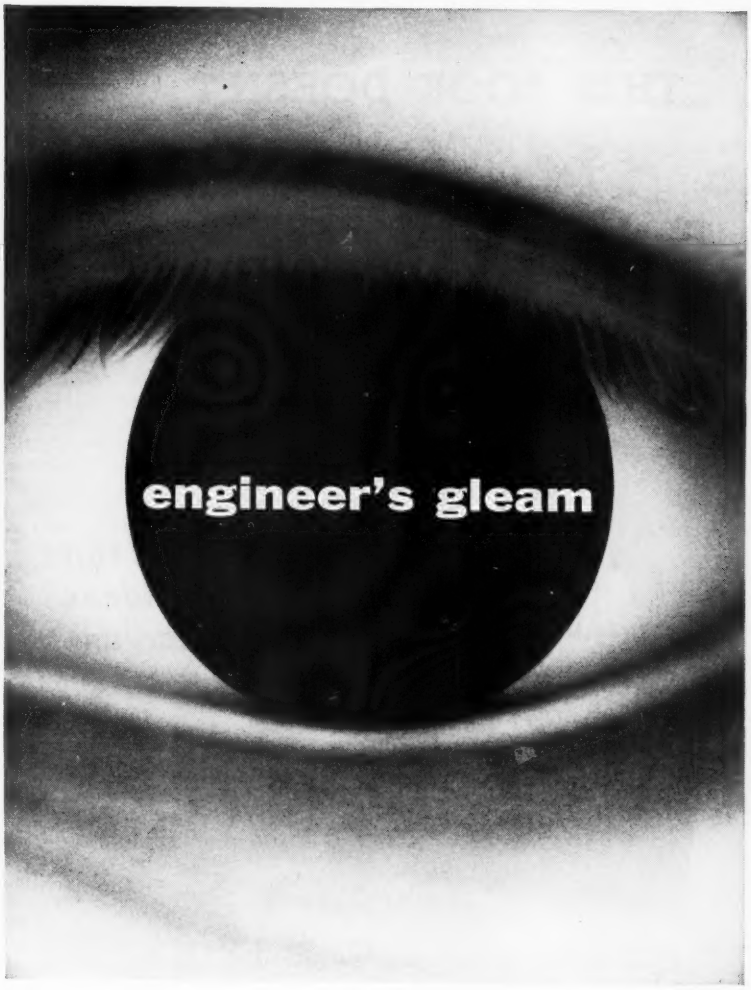

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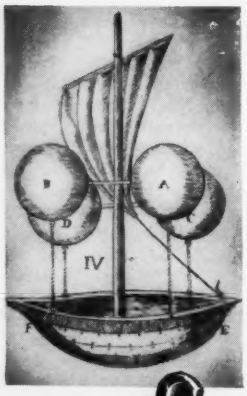

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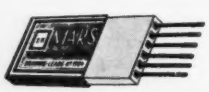

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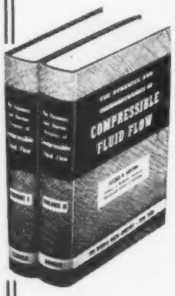

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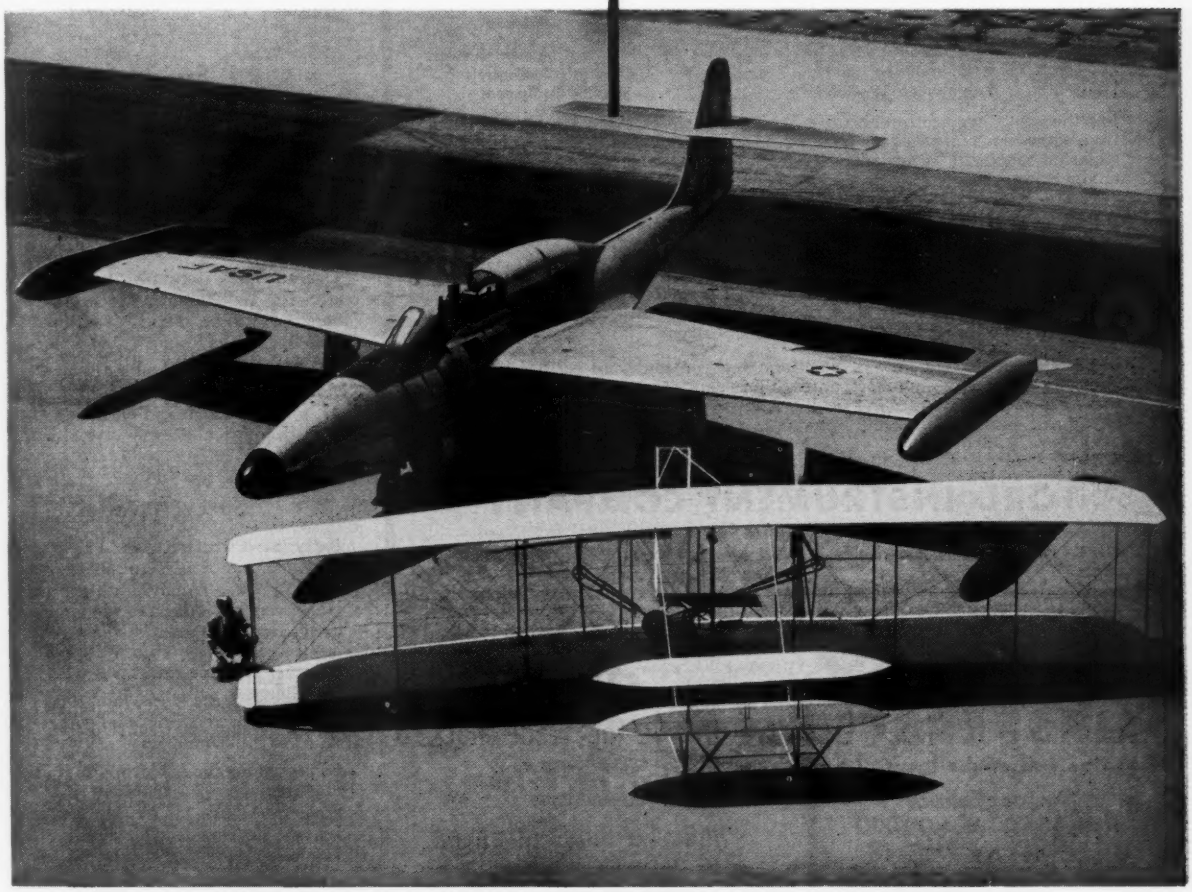

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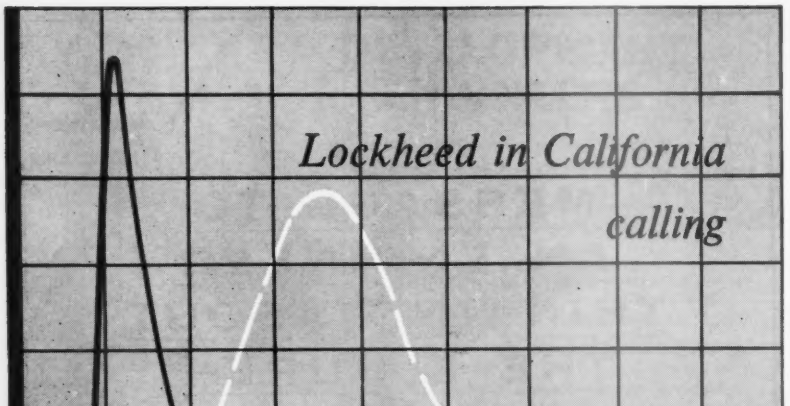

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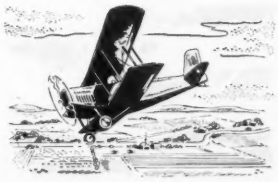

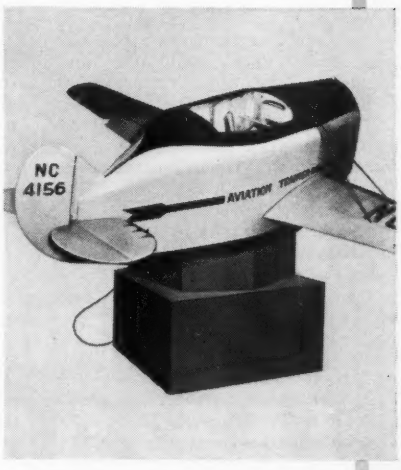

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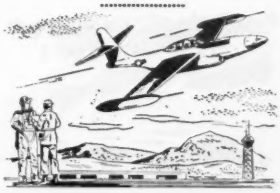

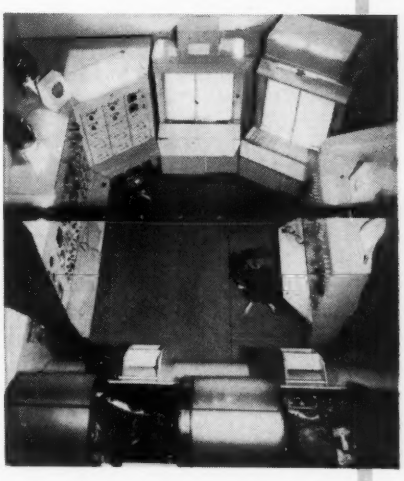

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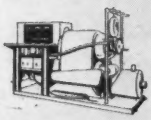

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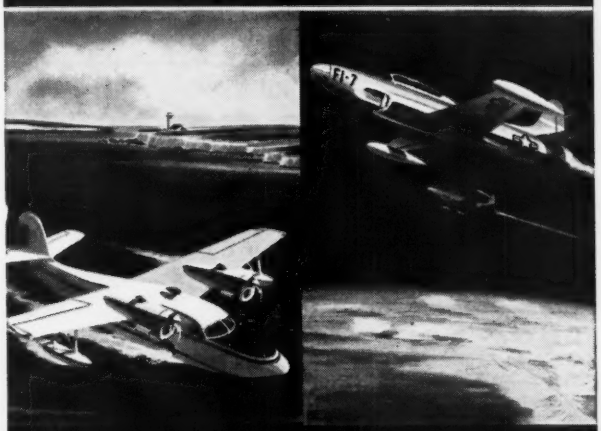

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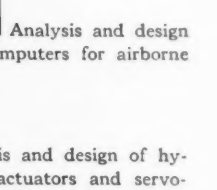

Aeronautical Reviews — BOOKS

Book Notes

AERODYNAMICS

A Selection of Tables for Use in Calculations of Compressible Airflow. Prepared on behalf of the Aeronautical Research Council by the Compressible Flow Tables Panel: L. Rosehead (Chairman), W. G. Bickley, C. W. Jones, L. F. Nicholson, C. K. Thornhill, and R. C. Tomlinson. Oxford, at the Clarendon Press; New York, Oxford University Press, 1952. 143 pp., figs. $8.00.

This book contains tables of some mathematical functions that occur in the theory of the steady flow of a compressible polytropic gas for which γ, the ratio of its specific heats, is 1:4; to a good approximation, air at moderate pressures and temperatures may be considered to be such a gas (the tables in this volume are limited to air). A selection of the actual functions most commonly used in calculations of compressible flow was made and have been grouped under the headings (i) Isentropic Flow, (ii) Characteristics, (iii) Shocks, (iv) Reduction of Pressure Ratios, (v) Powers of x and $(1 - x^2)$, and (vi) Miscellaneous. To these is added a List of Useful Functions of γ. The tables do not contain lists of values determined from experiment; they do, however, contain tabulations whose precise numerical values depend on experimental determinations of quantities such as γ, the ratio of the specific heats, and μ, the coefficient of viscosity. A companion volume of Graphs is being prepared.

AVIATION MEDICINE

Proceedings of a Symposium on Frontiers of Man-Controlled Flight. Presented at Los Angeles, April 3, 1953 by the Institute of Transportation and Traffic Engineering and University Extension, University of California, in collaboration with the Aero-Medical Engineering Association and the Institute of the Aeronautical Sciences, Los Angeles Section. Edited by Heinz Haber. Los Angeles, University of California, Institute of Transportation and Traffic Engineering, University of California, 1953. 109 pp., illus., diagrs., figs. $2.00.

Contents: Preface, John H. Mathewson. Preface, Harold Luskin. Introduction, John R. Poppen. Aircraft Performance in the Foreseeable Future, Edgar Schmued. Crew Compartment Atmosphere, Charles F. Lombard. Thermal Stresses in the Modern Aircraft, Konrad J. K. Buettner. Limitations to Noise and Vibration Control, Stanley Lippert. Radiation Hazards in High Altitude Aviation, Cornelius A. Tobias. The Mechanical Environment in the Future Aircraft, Heinz Haber. Impact and Dynamic Response of the Body, Herman P. Roth. Viewpoint of the Military Test Pilot, Charles E. Yeager. Viewpoint of the Commercial Transport Pilot, C. M. Christenson. Combined Physiological Stresses, W. V. Blockley. Characteristics of the Human Operator, John H. Lyman. Pilot Fitness, Development and Maintenance, Lawrence E. Morehouse. Data Presentation and Control Devices, Stanley N. Roscoe. Non-Transferable Functions, Neil D. Warren. The Electronic Assist, Robert J. Shank. Engineering the Cockpit for the Man, Alfred M. Mayo. Reality in Research, Joseph Kaplan. Panel Discussion on Frontiers of Man-Controlled Flight. Index.

CONTROL SYSTEMS

Discontinuous Automatic Control. Irmgaard Flügge-Lotz. Princeton, N.J., Princeton University Press, 1953. 168 pp., figs. $5.00.

In automatic control systems discontinuously working elements (on-off controls) are widely used. Their principal advantage is derived from their simple construction, but they produce complicated phenomena in the controlled system. Mechanical systems that have restoring forces, other than that of the control device, form the subject of this monograph. The theory is sufficiently developed to allow the design of discontinuous control systems with optimum efficiency. Their motions under the influence of discontinuous controls are studied in detail. In Chapter 8 the longitudinal motion of a missile under position control is studied in detail. The methods and results are not restricted to mechanical systems, but they apply also to thermodynamic and electrical systems. The only assumptions made are that the uncontrolled motion should be described by a linear differential equation or by a system of such equations. In other words, the uncontrolled motion should be represented by the superposition of damped or undamped sinusoidal oscillations or by exponential functions. Dr. Flügge-Lotz is associated with Stanford University.

HELICOPTERS

Helicopter Operation and Design Requirements. A condensed record of the symposium held during the Sixth Annual Technical Conference of IATA at Puerto Rico in April, 1953. (Doc. Gen. 1357.) Montreal, International Air Transport Association, 1954. 183 pp. $6.00.

This book is the product of a meeting held by IATA in which designers and manufacturers participated in an exchange of information with present and potential users of helicopters, armed forces, government agencies, research laboratories, and others, on the basis of an exhaustive and coordinated questionnaire agenda. The conclusions of the Symposium, which have since been endorsed by the IATA Technical Committee as a list of priorities for further development of the machine in scheduled transport, form an important part of the record. A valuable feature of the book is formed by the chapters devoted to the economic and physical characteristics of helicopter operations as they will affect heliports and other landing areas, zoning and similar matters of interest to city planners, municipal authorities, local transport operators, and the like.

For Information on IAS Library Service Facilities, see page 99

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

MATERIALS

Materials and Processes. James F. Young. 2nd Ed. New York, John Wiley & Sons, Inc., 1954. 1,074 pp., illus., diagrs., figs. $8.50.

As in the first edition, published in 1943, the emphasis has been placed on presenting a broad study of engineering materials and manufacturing processes from the viewpoint of the engineer. New chapters have been added on Metallographic Examination; Structure and Properties of Nonmetallic Materials; Rubber; Ceramics, Porcelain, and Glass; Miscellaneous Nonmetallic Materials; and Statistical Methods Useful in Quality Control. Sections have been added on Tarnishing, Electric Contacts, and Nondestructive Testing. The coverage has been expanded on many subjects, such as bearing metals, superalloys, nonferrous elements, blow molding, shell molding, and pressure welding. Bibliographies are included for readers desiring specialized treatments. The volume is one of a series written in the interest of the General Electric Engineering Educational Programs.

MATHEMATICS

Stability Theory of Differential Equations. Richard Bellman. New York, McGraw-Hill Book Company, Inc., 1953. 166 pp., figs. $5.50.

This graduate text furnishes an introduction to the modern theory of stability and asymptotic behavior of solutions of linear and nonlinear differential equations. The linear equation with constant and almost-constant coefficients is treated in great detail, using matrix theory. To make the book as self-contained as possible, the results in matrix theory required for stability theory are derived from the beginning, assuming no previous acquaintance with matrix theory. The results of the linear theory are used to derive results of Poincaré and Liapounoff concerning the stability of nonlinear systems. Following this, a survey of the important results concerning the boundedness, stability, and asymptotic behavior of second-order linear differential equations is presented. The last two chapters are devoted to some important nonlinear differential equations whose solutions may be completely described as far as asymptotic behavior is concerned. The author, who is with The RAND Corporation, has provided brief bibliographies at the ends of chapters.

RESEARCH

Research Operations in Industry. Papers delivered at the 3rd Annual Conference on Industrial Research, June, 1952, with Selected Papers from the 1st and 2nd Conferences. Sponsored by the Department of Industrial Engineering, Columbia University. David B. Hertz, Editor.

Albert H. Rubenstein, Assistant Editor. New York, King's Crown Press, 1953. 453 pp. $8.50.

Listed below are the papers presented at the 3d Conference: The Design of Research Projects and Programs, Waldo H. Kliever. Management's Appraisal of Industrial Research, Don G. Mitchell. Preparing Research Budgets, Robert N. Anthony. Designing Conveniences for Research, Ralph Thomas Walker. Planning a Large Medical Research Center, Albert F. Siepert. Introduction to the Concept of the Designed Experiment, Russell A. Ackoff. The Growth of Experimental Design in a Research Laboratory, John W. Tukey. Principles of Experimental Design, W. J. Youden. Phases of Operations Research, C. West Churchman. Some Applications of Operations Research in Industry, O. W. Hamilton. Organizations of Operations Research, Philip M. Morse. Some Comments on Operations Research, R. T. Eddison. Communication of Research Information between Large Groups, Eugene W. Scott. Design for Research Communications, Albert H. Rubenstein. Technical Information Services for Business, John C. Green.

ROCKETS

High-Altitude Rocket Research. Homer E. Newell, Jr. New York, Academic Press, Inc., 1953. 298 pp., illus., diagrs., figs. $7.50.

The primary aim of this book is to bring before the reader the principal results of upper-air rocket research which have been published in the unclassified literature during the past six or seven years. Enough background information is provided to enable the reader to understand the experiments described and to see in a broad way the overall significance of the results. The scope of the review is limited to rocket-borne experiments, and no attempt is made to cover the whole field of upper air research. The first chapter gives a brief sketch of the upper atmosphere, an outline of the history of rockets, and an introductory review of this country's upper-air rocket program. Chapters 2 and 3 discuss in a general way research and instrumentation techniques, and experimental difficulties peculiar to rockets. Illustrative examples are taken from actual rocket flights and experiments, and key equipments such as telemeters are described. Beginning with Chapter 4, published results of the rocket upper-air program are presented. Each chapter treats of a single subject, as follows: atmospheric winds, solar radiation, atmospheric composition, the ionosphere, cosmic rays, and high-altitude photography. The experiments and results are reported without detailed critique, but an attempt is made to bring out the sources of error in each case and their significance. References to available unclassified literature are given at the ends of chapters. The WAC Corporal, V-2, Aerobee, and Viking rockets are described, and all the upper-air research firings conducted by U.S. agencies from early 1946 to December 31, 1952, are listed. The author is Head, Rocket-Sonde Research Branch, Naval Research Laboratory, Washington, D.C.

THERMODYNAMICS

Flames; Their Structure, Radiation, and Temperature. A. Gaydon and H. G. Wolfhead. London, Chapman & Hall Ltd., 1953. 340 pp., illus., diagrs., figs. 55s.

This text forms a fairly advanced discussion of that part of the field of combustion concerned with stationary flames, with emphasis on the physical rather than the chemical point of view. Quantitative measurements are made use of, but purely mathematical discussion has been avoided. Dr. Gaydon is associated with the Chemical Engineering Department of the Imperial College; Dr. Wolfhead is Principal Scientific Officer, Royal Aircraft Establishment.

Contents: (1) Introduction. (2) Premixed Flames. (3) Flow Patterns and Flame Shapes. (4) Measurements of Burning Velocity. (5) The Mechanism of Flame Propagation. (6) Diffusion Flames. (7) Unstable Flames. (8) Solid Carbon in Flames. (9) Radiation Processes in Flames. (10) Flame Temperature: I, Measurement by the Spectrum-line Reversal Method. (11) Flame Temperature: II, Other Methods of Measurement. (12) Flame Temperature: III, Calculated Values. (13) Ionisation in Flames. (14) Some Unusual Flames. (15) Some Flame Problems. References (10 pages). Author Index. Subject Index.

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"Fifty Years of Flight"—A Chronicle of the Aviation Industry in America, 1903–1953, Welman A. Shrader (Published by Eaton Manufacturing Company. Reprinting and Distribution Rights Granted to IAS)	4.50	5.00

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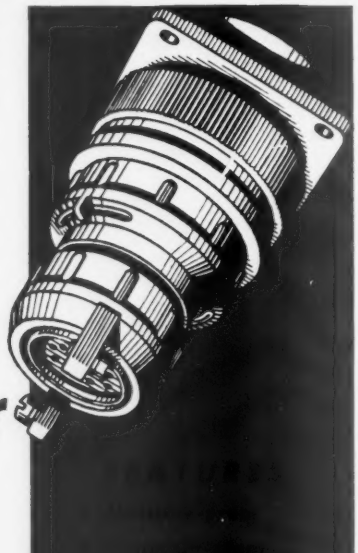

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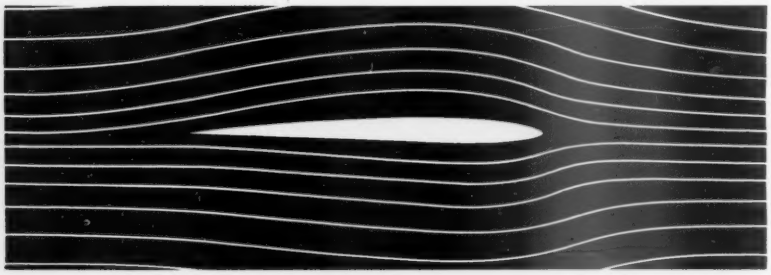

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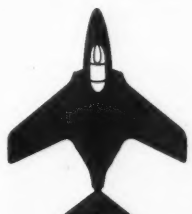

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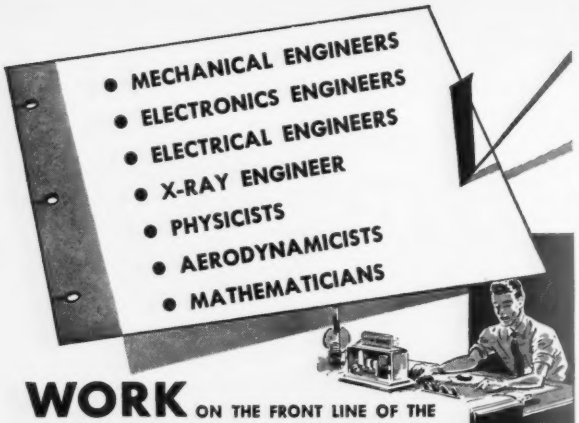

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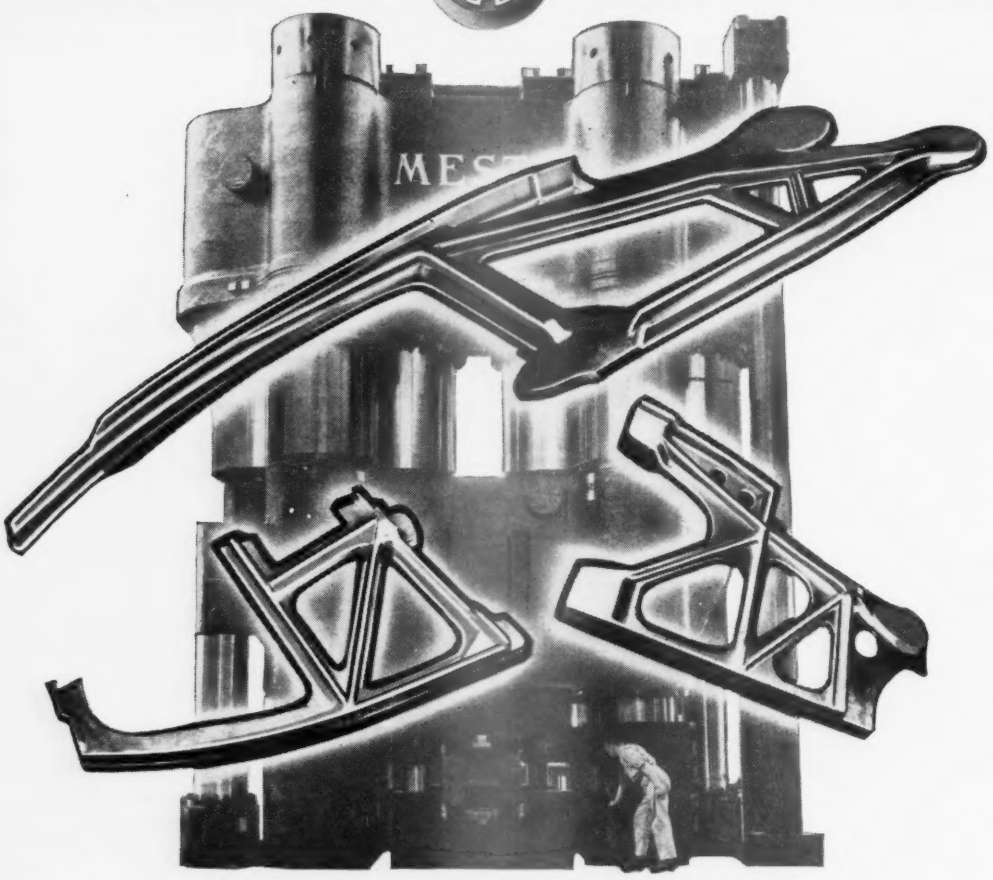

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"Etchall" Identification Marker. This rubber stamp device imprints with an acid stain on all types of metal. **Acme Marking Co., Dept., 102, 8030 Lyndon, Detroit 38, Mich.**

Multi-Purpose, Extreme Pressure Lubricant. Bulletin No. 101 describes "Molykote," type BR-2. **The Alpha Corp., 179 Hamilton Ave., Greenwich, Conn.**

Paramount Brand Felt Products. Descriptive twelve-page catalog. **Bacon Felt Co., West Water St., Tauton, Mass.**

Anti-Static Solution. Eliminates static charges on aircraft canopies and windows. **Chemical Development Corp., Danvers, Mass.**

Industrial Cork Products. Descriptive four-page bulletin No. S-54. **Dodge Cork Co., Inc., Lancaster, Pa.**

"Lebanon" Steel Slide Chart. Gives reference data on nineteen carbon and low-alloy steels and seventeen stainless and corrosion-resistance steels. **Lebanon Steel Foundry, 47 Lehman St., Lebanon, Pa.**

Injection Molding of Silicone Rubber Products. Descriptive literature. **Dept. KP, Minnesota Rubber & Gasket Co., 5724 W. 36th St., Minneapolis 16, Minn.**

"Frost Buster." A de-icing compound to remove ice and frost from aircraft. **Octagon Process Inc., 15 Bank St., Staten Island 1, N.Y.**

Investment Casting Process. Eight-page brochure gives solutions to production of small metal parts problems. **Vascoloy-Ramet Corp., Waukegan, Ill.**

AIRCRAFT PARTS & EQUIPMENT

Two-Step Time Delay Relay. Descriptive 4-page bulletin No. SR4. **AGA Div., Elastic Stop Nut Corp. of America, Elizabeth, N. J.**

Aircraft Skin Milling Facilities. Descriptive bulletin includes a complete set of data sheets, including number of skin mills available and capacities for each. **Franklin Balmar Corp., Woodberry, Baltimore 11, Md.**

Copper Plated Gears. Eight-page descriptive brochure. **Brad Foote Gear Works, Inc., Cicero 50, Ill.**

Seamless Metal Hose. Ten-page descriptive catalog No. 100. **Cobra Metal Hose Div., DK Mfg. Co., 4640 W. 54th St., Chicago 32, Ill.**

FC5 Flight Control System. Technical descriptive bulletin No. GET-2416. **General Electric Co., 1 River Rd., Schenectady 5, N.Y.**

Quick Disconnect Cable Unit. A chuck-like locking unit with sliding collar eliminates endplay and looseness. **Hydraulic Products Co., 80 Federal St., Boston, Mass.**

Rotomotive Equipment for Aircraft. Bulletin No. 6014 describes engine starters, generators, motors, actuators, etc. **Jack & Heintz, Inc., 17600 Broadway, Cleveland 1, Ohio.**

Mechanical-Electric Translator. For automatic control of r.p.m. of aircraft engines and helicopter rotors. **Kahn & Co., Inc., 541 Windsor St., Hartford 1, Conn.**

"The Lycoming Story." Forty-page company brochure describes products, functions, and personnel. **Lycoming Div., Avco Mfg. Corp., Stratford, Conn.**

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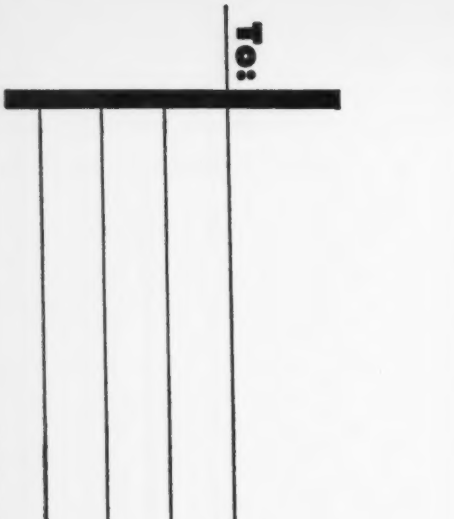

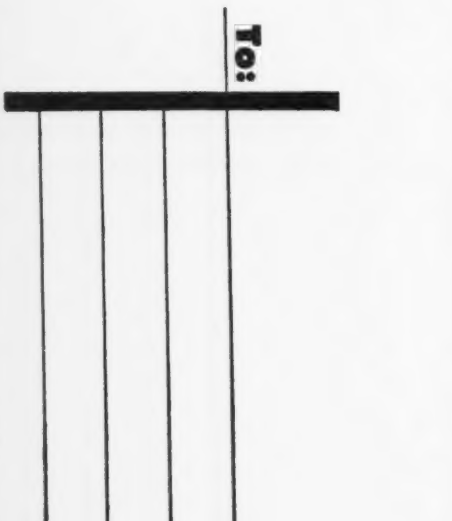

Gyros. Descriptive booklet gives complete information on all rate, vertical, cageable vertical and floated gyros. **Minneapolis-Honeywell Regulator Co., Aeronautical Div., 2600 Ridgway Rd., Minneapolis 13, Minn.**

Lightweight Fuel Gage Systems. Descriptive booklet. **Minneapolis-Honeywell Regulator Co., Aeronautical Div., 2600 Ridgway Rd., Minneapolis 13, Minn.**

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Stud & Insert All-Purpose Kits. Each kit contains one size of inserts or studs, with locking rings, installation tools, and directions for use. **Rosan, Inc., 625 Coast Highway, Newport Beach, Calif.**

Engineer's Manual on "Paneloc" Aircraft Fasteners. Fifty-eight page descriptive catalog No. C-316. **Scovill Mfg. Co., Aircraft Fastener Div., 99 Mill St., Waterbury 20, Conn.**

All-Metal Clinch Locknuts. A special-purpose fastener for mounting parts or assemblies on thin-section material. **Standard Pressed Steel Co., Jenkintown, Pa.**

Titanium Bolts. For use in airframe and aircraft engines. **Standard Pressed Steel Co., Jenkintown, Pa.**

Servo Pumps and Their Application. Nineteen-page descriptive booklet No. SE-15. **Vickers, Inc., 1400 Oakman Blvd., Detroit 32, Mich.**

Small Electric Brakes & Clutches. For control of low-torque servo drives, instruments, etc. **Warner Electric Brake & Clutch Co., Beloit, Wis.**

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Metalized Ceramic Insulators and Terminals. These units are for hard-solder applications, and of use wherever a wide range of temperatures and severe thermal shock are encountered. **Advanced Vacuum Products, Inc., 22 Liberty St., Stamford, Conn.**

Folded Hybrid Junctions. This series is essentially a modification of the familiar "tee" outlet in that the two side arms have been folded back to share a common wall. **Airtron, Inc., Dept. H, Linden, N. J.**

"Circuitry." Descriptive bulletin No. 112 explains the functioning of 11 control and alarm circuits utilizing meter-relays. **Assembly Products, Inc. Main at Bell St., Chagrin Falls, Ohio.**

"Hy-Met" High-Temperature Capacitors. These metallized paper capacitors feature a solid thermosetting impregnant which eliminates possibilities of impregnant leakage. Bulletin No. AB-19. **Astron Corp., 255 Grant Ave., East Newark, N. J.**

Electronic Chopper. Model 207 operates on a new principle involving the modulation of d.c. voltages by alternate illumination at line frequency of the photoconductive element in a voltage divider. **Avion Instrument Corp., 299-34 State Highway No. 17, Paramus, N. J.**

"Celco" Radar Deflection Yokes. Rotating and stationary types for PPI and rectangular displays. **Constantine Radio Laboratories, Mahwah, N.J.**

Pulse Capacitor & Pulse Forming Networks. Bulletin describes design and production facilities. **Corson Electric Mfg. Corp., 540 39th St., Union City, N.J.**

Aircraft Navigation and Communications Equipment. Catalog describes accessories and test equipment. **Dayton Aviation & Equipment Corp., Vandalia, Ohio.**

Air-Damp Dashpot. For use as a system stabilizer in control mechanisms and switchgear. **Electric Regulator Corp., Norwalk, Conn.**

Voltage Sensitometer. Designed to protect electronic equipment or controls which might not operate properly on low voltage—or might be sensitive to voltage fluctuations or failure of the various aircraft power supplies. **Electronic Specialty Co., 3456 Glendale Blvd., Los Angeles 39, Calif.**

Two-Oz. Miniaturized Permanent Magnet D.C. Motor. Type SS measures $^7/_8$" diam. by $1^3/_8$" long. **Globe Industries, Inc., P.O. Box 101, N. Dayton Station, Dayton, Ohio.**

Series "J" Single Turn, Continuous-Rotation Potentiometers. Power rating is 4 watts at 40°C. ambient; resistance from 2 ohms to 100,000 ohms can be provided. **Helipot Corp., 916 Meridian Ave., South Pasadena, Calif.**

High-G Power Relay. Designed to operate under the high temperature, shock, and frequency vibration found in military aircraft, rockets, and guided missiles. **Hetherington, Inc., Sharon Hill, Pa.**

Directional Radomes. A new sandwich construction permits the transmission of microwaves at any angle of incidence without alteration of polarization,

and with or without change of direction. **McMillan Laboratory, Inc., 28 Central St., Ipswich, Mass.**

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Midget Chopper. This two-ounce unit can be used either as a d.c.-a.c. modulator or as a rectifier. **Minneapolis-Honeywell Regulator Co., Aeronautical Div., 2600 Ridgway Rd., Minneapolis 13, Minn.**

Epoxy Type Electrical Insulation Resin. Has a usable life of from three to five days before setting up. **Minnesota Mining & Mfg. Co., 900 Fauquier St., St. Paul 6, Minn.**

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200°C. Miniaturized Capacitor. Capacitance variance is less than 5% from −80°C. to +200°C. **National Capacitor Co., 385 Washington St., Quincy, Mass.**

Magnetic Amplifier Regulated Power Supply. Model MR1032-50 is rated at 10–32 volts d.c. at 50 amp. continuously with magnetic amplifier regulation of ±1%. **Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.**

Relay Data File. Contains specifications and photographs of 42 relay types. **Price Electric Corp., Frederick, Md.**

Radar Altimeter. Keeps pilot informed at all times of his height above the surface of the earth (not sea level). **Raytheon Mfg. Co., Waltham, Mass.**

High Temperature Electrical Connector. Carries vital circuits through aircraft fire walls, and other high ambient areas. **Scintilla Div., Bendix Aviation Corp., Sidney, N.Y.**

Subminiature Trimmer Potentiometers. These 1/4-oz. units are 1/2" in diameter by approximately 1" long exclusive of shaft. **The Technology Instrument Corp., Acton, Mass.**

Miniature Circular Connectors. Polarizing is accomplished by means of a keyway in the receptacle. **Viking Electric, 1061 Ingraham St., Los Angeles 17, Calif.**

Transductor Magnetic Amplifier. Eight-page technical booklet No. TD 52-601. **Westinghouse Electric Corp., P.O. Box 2099, Pittsburgh 30, Pa.**

"Wheelco" Instruments for Industrial Process Control Application. Descriptive bulletin No. F 5633-1. **Wheelco Instruments Div., Barber-Colman Co., Rockford, Ill.**

Repeat Cycle Electronic Timers. Provide on-cycles ranging from 0.01 to 150 seconds, and off-cycles ranging from 0.01 to 900 seconds. Bulletin No. 353. **G. C. Wilson & Co., 1950 Eighth Ave., Huntington, W.Va.**

PRODUCTION & MAINTENANCE EQUIPMENT

Mobile Heater. Provides temporary heating for hangars and large sheds and also preheats engines. **Besler Corp., Oakland, Calif.**

1954 "Calrod" Heating Catalog. This 60 page booklet No. GEC-1005E describes all types of industrial heaters and heating devices. **General Electric Co., 1 River Rd., Schenectady 5, N.Y.**

Heavy Duty Cold Chamber Type Die Casting Machine. Model HD-303 is particularly adapted to casting aluminum alloys at high speed from either single or multiple cavity dies. **Harvill Mfg. Co., Corona, Calif.**

Milling Cutter. Permits simultaneous milling of multiple slots in a magnesium extrusion. **I-T-E Circuit Breaker Co., Special Products Div., Philadelphia, Pa.**

Gas Engine Power Unit. For servicing aircraft with either 12- or 24-volt electrical systems. Bulletin MGC-107. **Motor Generator Corp., W. Water St., Troy, Ohio.**

Emergency Lighting Unit. Model 200 X provides 10,000 candle power or more of emergency lighting which automatically illuminates large areas during power failures. **Sentry-Lite, 55 Front St., Rockville Centre, N.Y.**

Automatic Flush Riveting Machines. Designed for rapid joining of high-tensile strength aluminum alloys such as 24ST81, 24ST86, 75ST6, and 78ST6. **T. W. & C. B. Sheridan Co., 135 Lafayette St., New York 13, N.Y.**

Glass Cloth Photo-Template Material. For use in mapping, tooling, lofting, plane table surveying, etc. **Tru-Scale Engr. Supply Co., Wichita, Kan.**

Mold Release. Type V-1 for injection molding of all thermoplastics. **Vin-Rock, Inc., 8211 Almira Ave., Cleveland 2, Ohio.**

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"S" Band Wavemeter. Model 229 is a coaxial-line type instrument covering the frequency range from 2.3 to 4.5 KMC. **Amerac, Inc., Wenham, Mass.**

Universal Electrical Calibrating Instruments. Have wide capacity ranges for calibrating and proving testing machines and other measuring equipment under loads in both tension and compression. **Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.**

Climate-Survey Temperature Indicators. These instruments can be used with various sensing-element arrangements including aspirated shields, probes, aircraft wing-mounted shields, perforated and Thornthwaite shields. **Beckman & Whitley, Inc., 902 E. San Carlos Ave., San Carlos, Calif.**

Digital Differential Analyzer Computer. Utilizes the decimal numbering system in both programming and in calculating solutions. **Bendix Computer Div., 5630 Arbor Vitae, Los Angeles, Calif.**

Small Portable Environmental Chambers. Working areas of 1 to 64 cu. ft. **Conrad, Inc., Holland, Mich.**

Automatic Wave Analyzer. Provides Fourier analysis of vibration and similar data. Bulletin No. 54-C. **The Davies Laboratories, Inc., 4705 Queensbury Rd., Riverdale, Md.**

Electronic Temperature Controller. Suitable for use in laboratory work. **Fielden Instrument Div., Robertshaw-Fulton Controls Co., 2920 N. 4th St., Philadelphia, Pa.**

High Speed G-Accelerator. Capable of testing accelerometers and other instruments under acceleration forces up to 850 G's. **Genisco, Inc., 2233 Federal Ave., Los Angeles 64, Calif.**

Low-Head Type Differential-Pressure Pneumatic Transmitter. For measuring liquid fuels, and the automatic control of fuel-air ratio. Bulletin No. 2753. **Hagan Corp., Pittsburgh, Pa.**

Ring Balance Meter Signal Transmitter. For remote metering and control applications including control installations requiring reset, remote adjustable set point, and rate action. **Hagan Corp., Pittsburgh, Pa.**

Remote Area Monitoring System. For radiation measurements. **Jordan Electronic Sales, 119 E. Union St., Pasadena, Calif.**

Supersonic Machmeter. This instrument has a range from Mach Number 0.7 to 3.0, and from sea level to 80,000 ft., or up to three times the speed of sound. **Kollsman Instrument Corp., 80–08 45th Ave., Elmhurst, N.Y.**

Magnetic Recording of Information. Four-page illustrated pamphlet on "Airfloating." **Logistics Research, Inc., 141 S. Pacific, Redondo Beach, Calif.**

Pressure Gauge Catalog. 124 pages on Ashcroft pressure gauges, gauge accessories, and gauge engineering information. **Manning, Maxwell & Moore, Inc., Stratford, Conn.**

Automatic Pen-Lifting Device. Designed for single-record strip chart recorders. **Minneapolis-Honeywell Regulator Co., Industrial Div., Philadelphia, Pa.**

Electronik Duplex Function Plotter. This electronic instrument automatically measures two variable conditions and simultaneously plots their relationship to a third. **Minneapolis-Honeywell Regulator Co., Industrial Div., Philadelphia, Pa.**

High-Speed Digital Magnetic Tape Handler. Model 902 applications include storage of telemetered data for use in computers. **Potter Instrument Co., 115 Cutter Mill Rd., Great Neck, N.Y.**

Electrolimit Universal Internal Comparator. Model "D" designed for accuracy in the checking of internal diameters from $^1/_{16}$" to $^1/_4$" inclusive. Sixteen-page bulletin available. **Pratt & Whitney Div., Niles-Bement-Pond Co., West Hartford 1, Conn.**

Oscillographic Recording Systems and Accessories. Thirty-eight page descriptive catalog. **Sanborn Co., Industrial Div., 195 Mass. Ave., Cambridge 39, Mass.**

"Some Design Considerations for Liquid Rotor Angular Accelerometers." Four-page folder entitled, "Instrument Notes." **Statham Laboratories, Inc., 12401 W. Olympic Blvd., Los Angeles 64, Calif.**

Explosion Test Chambers. Descriptive four-page bulletin. **Tenney Engineering, Inc., 26 Ave. B, Newark 5, N.J.**

Dual Recording Milliammeter. This portable 15$^1/_2$-lb. recorder utilizes magnetic fluid clutches as the basic component of the meter movements. **Texas Instruments, Inc., 6000 Lemmon Ave., Dallas 9, Tex.**

"Electodyne" Electronic Balancing Machines. Automatically measures the amount and indicates the angular location of unbalance by means of electronics. Descriptive bulletin No. 49. **Tinius Olsen Testing Machine Co., 3012 Easton Rd., Willow Grove, Pa.**

Method of Checking Materials Uniformity. This ultrasonic testing system indicates the physical properties of materials and detects flaws and minute defects. **Vibro Ceramics Corp., Metuchen, N.J.**

Test Chamber. Model A-30-40FH is designed for large capacity testing at temperature range between −40°F. to +200°F. **Webber Mfg. Co., Inc., Dept. 361, 2740 Madison Ave., Indianapolis 3, Ind.**